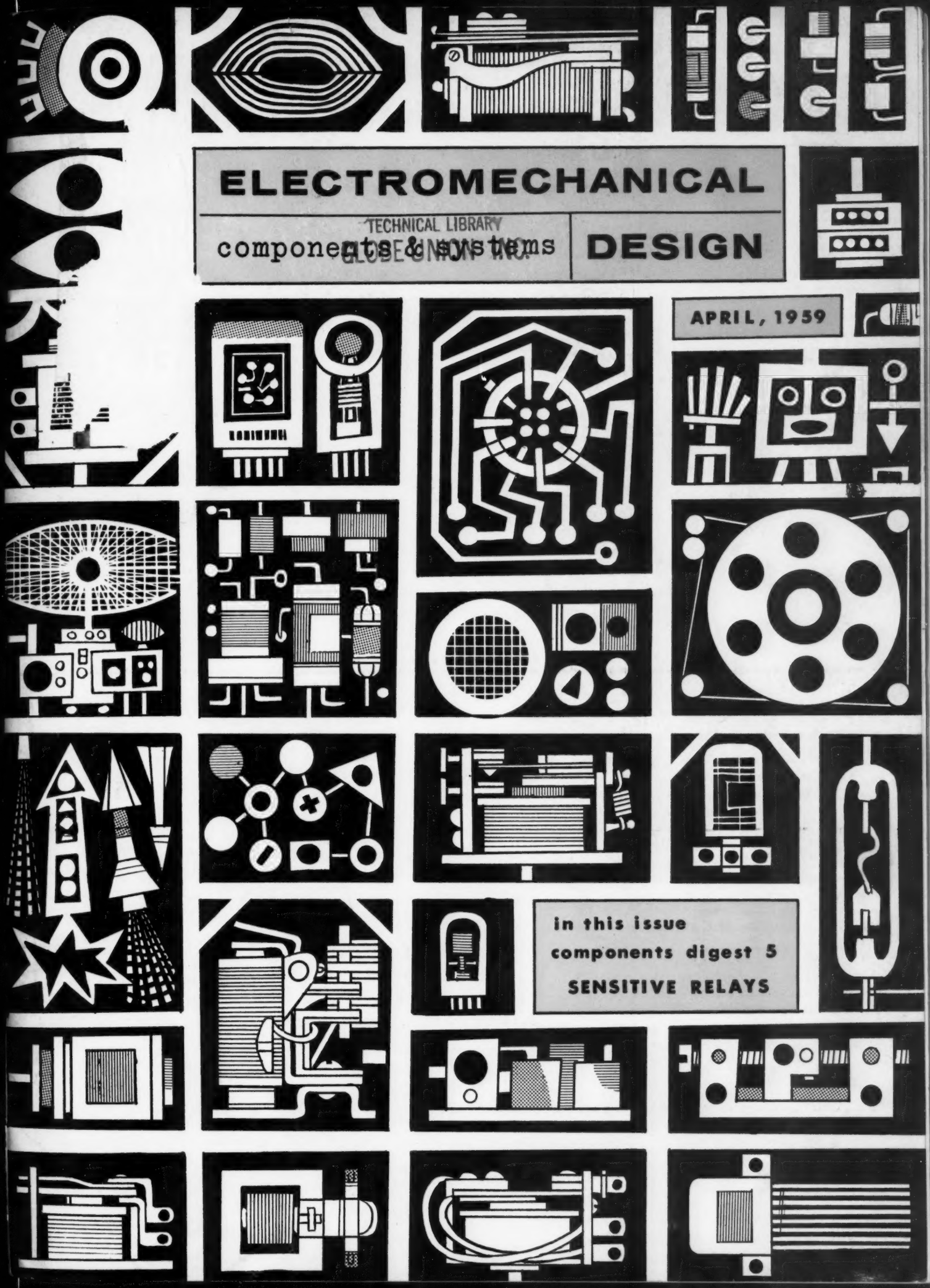


ELECTROMECHANICAL

components & systems

DESIGN

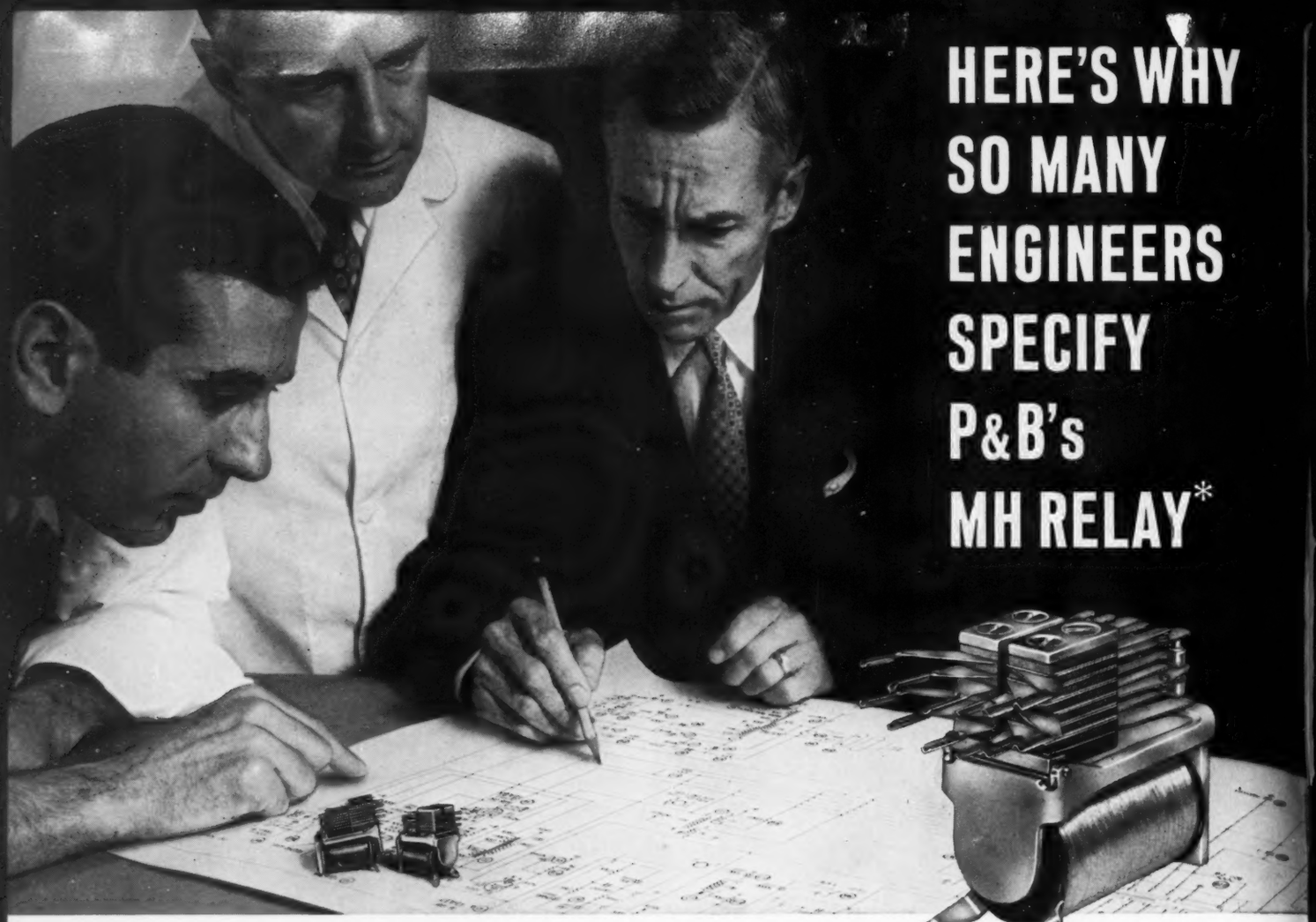
TECHNICAL LIBRARY
GLOBE-UNION INC.

APRIL, 1959

in this issue

components digest 5

SENSITIVE RELAYS



HERE'S WHY SO MANY ENGINEERS SPECIFY P&B's MH RELAY*

*AND VARIATIONS OF THIS BASIC STRUCTURE SHOWN BELOW

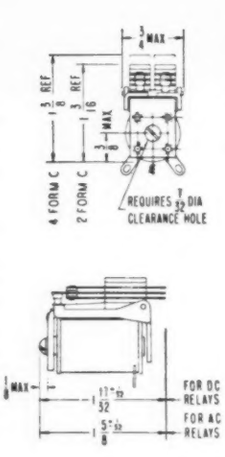
Shown with printed circuit terminals

VERSATILITY

and adaptability are prime reasons why designers have made the MH a P&B best seller. This relay series, for example, does yeoman duty in such diverse applications as jet aircraft, street lighting equipment, computers and missile ground controls.

When multiple switching is required...when size, weight, long life and reliability are critical ...our MH relay can usually fill the bill. It's RIGHT for countless jobs, often at countable savings.

Let us send you complete information about this miniature telephone-type relay and the variations we've evolved for special applications. Write or call today.



ENGINEERING DATA/MH RELAY

Insulation: Laminated phenolic.

Insulation Resistance: 100 megohms minimum.

Breakdown Voltage: 500 volts RMS between all elements.

Shock: Up to 30g.

Vibration: Up to 10g from 55 to 500 cps.; .065" max. excursions from 10 to 55 cps.

Ambient Temperature: −45°C. to +85°C. −(65°C. to +125°C. on special order).

Weight: 2½ oz. max. (open relay)

Pull-In: Approx. 75% of nominal voltage.

Pull-In Speed: Approx. 15 ms.

Drop-Out Speed: Approx. 10 ms.

Terminals: Pierced solder lugs; special lugs for printed circuits, taper tab (AMP #78).

CONTACTS:

Arrangements: Up to 9 springs per stack.

Material: ⅛" silver; also Palladium or gold alloy.

Load: Dry circuits to 5 amps @115V AC resistive.

COILS:

Resistance: 22,000 ohms max.

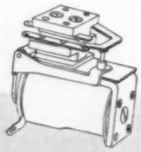
Power: 100 milliwatts per movable minimum to 4 watts at 25°C. max. (200 mw. min. to meet max. shock/vibration spec.)

Duty: DC: Continuous. AC: Intermittent (2 pole relay max.)

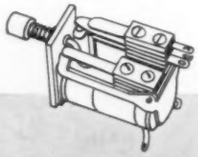
Voltages: DC: Up to 110 volts. AC: Up to 230 v. 60 cycles.

Current: 2.5 ma to 10 amps DC.

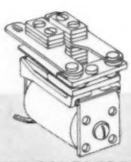
P&B STANDARD RELAYS AVAILABLE AT YOUR LOCAL ELECTRONIC PARTS DISTRIBUTOR



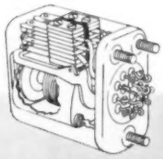
MC FOR RF SWITCHING
For RF switching where intercontact capacitance losses must be minimized. Ceramic contact spacers.



MA LATCHING
Electrical latch; mechanical reset. Small, versatile and offered with selection of contact arrangements.



MB CONTACTOR
Contacts rated 60 amp. 28 volts DC non-inductive. Will carry 150 amp. surge for a duration of 0.3 seconds.



MH SEAL-TEMP
Features sealed coil to minimize contact contamination. Available as hermetically sealed relay only.

POTTER & BRUMFIELD INC.

PRINCETON, INDIANA • SUBSIDIARY OF AMERICAN MACHINE & FOUNDRY COMPANY

CHANGE OF ADDRESS

PRINT NAME

DESIGNER CO. ADDRESS

CITY

STATE

Circle the code number for more information on editorial or advertised items. Code numbers for advertisements are listed in Advertiser's Index and when possible are set in the ad.

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81	82	83	84
85	86	87	88	89	90	91	92	93	94	95	96
97	98	99	100	101	102	103	104	105	106	107	108
109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132
133	134	135	136	137	138	139	140	141	142	143	144
145	146	147	148	149	150	151	152	153	154	155	156
157	158	159	160	161	162	163	164	165	166	167	168
169	170	171	172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189	190	191	192
193	194	195	196	197	198	199	200	201	202	203	204
205	206	207	208	209	210	211	212	213	214	215	216
217	218	219	220	221	222	223	224	225	226	227	228
229	230	231	232	233	234	235	236	237	238	239	240
241	242	243	244	245	246	247	248	249	250		

To facilitate processing your inquiries please check the appropriate box below.

☐ I am now ON your circulation list

☐ I am NOT on your circulation list

ELECTROMECHANICAL

components & systems | **DESIGN**

Please use this card before June 15

IF YOU ARE NOT ON OUR CIRCULATION LIST, YOU CAN QUALIFY FOR A YEAR'S FREE SUBSCRIPTION BY ANSWERING THE FOUR QUESTIONS BELOW

1. My major engineering function in research, development or design is: (check one only) ☐ *Electronic* ☐ *Electromechanical* ☐ *Mechanical*

2. My major non-engineering function in research, development or design is: (check all that apply) ☐ *Management* ☐ *Purchasing* ☐ *Production* ☐ *Other* _____

3. Principal product(s) manufactured by my company at the address below:

_____

4. No. of engineers in my dep't._____; in my company_____

PLEASE PRINT

NAME _____ TITLE _____

COMPANY _____

COMPANY ADDRESS (ST.) _____

CITY _____ ZONE _____ STATE _____

Signature _____

Postage Will Be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

First Class Permit No. 13772 • New York, N. Y.

ELECTROMECHANICAL DESIGN

1357 WASHINGTON STREET

WEST NEWTON 65, MASS.

The Sourcebook of Design Ideas in Applied Electromechanics

VOL. 3, NO. 4

APRIL 1959

ELECTROMECHANICAL components & systems DESIGN

CONTENTS

COMPONENTS DESIGN

4 MINIATURE CONTROL METER
No contacts at set point allows full scale indication and eliminates contact resistance, arcing and corrosion.

12 SILICON PNPN CONTROLLED SWITCH
New device achieves high gain, high speed, medium power switching beyond that possible with present-day transistors.

14 POWER TRANSMISSION PROGRESS
Maintenance free magnetic clutch.
Packaged electric clutch and sheave simplifies no-load starting.

21 PRINTED CIRCUIT MOTORS
Development of two-sided printed circuit boards with reliable plated through holes makes the cost, quality and engineering advantages of printed circuitry available for d-c motor design.

SYSTEMS DESIGN

26 NONLINEAR SYSTEMS
Dr. Norbert Wiener demonstrates methods of determining the contents of a "blackbox" so long as one knows what is going into the box and what is coming out.

MATERIALS

36 RADIATION AND MATERIALS, PART II
Staff columnist David Bandel discusses effects of high-level radiation on mechanical and electrical properties of materials.

TECHNIQUES

40 PACKAGE TECHNIQUES FOR SYSTEMS DESIGN
Beacon transmitter for satellite and space vehicles.
Subminiature rate gyro package.
One million parts fit into one cubic foot by microminiature technique.
Electronic "sardine sandwich" packages.

COMPONENTS DIGEST

45 SENSITIVE RELAYS
Basic relay parts
Magnetic circuit fundamentals
A-C vs d-c relays
Polarized relays
Effect of miniaturization
Contact arrangements
Relay coils
Hi-speed operation
Low speed operation
Construction features
Environmental requirements
Relay contacts
Dry circuits
Relay definitions
Charts of sensitive relay characteristics

DEPARTMENTS

69 ADVERTISERS' INDEX

70 PRODUCT INDEX

71 DATA SHEETS FOR YOUR THREE RING BINDER

← CIRCLE 1 ON INQUIRY CARD

New ASCOP

SHAFT POSITION DIGITAL ENCODERS

Ultra-Reliable in any Environment

For the first time a true digital transducer has been built that **can last 100 years in actual use.** It is the new ASCOP EPD8G Shaft Position Digital Encoder.

This new encoder requires **no contacts to read out,** either mechanical brushes or optical. Its **code is a permanent magnetic field** on a ferrite disk.

The new encoder performs to specs in the worst surroundings. Heat or cold, dust, humidity and severe vibration **don't affect it.** Read it out any number of times when it's at rest or rotating as fast as 10,000 rpm and the millionth reading will be just as accurate as the first. In fact, we know that this encoder out-performs any encoder of comparable accuracy under any conditions.

The EPD8G is ideal for such applications as numerical control of machine tools where it can outlast the machine. It can't be beat for obvious applications like reading out self-balancing potentiometers, radar antenna position, weather instruments, and navigation devices. Starting torque and inertia are so low as to be negligible.

Condensed Specifications

Resolution: ..... 2^8
Size: ..... 2¼" dia. x 1¼"
Weight: ..... 8 oz.
Code: ..... Gray
Inertia: ..... 70 gm-cm²
Starting Torque: 0.05 in. oz.
Operating Temperature: —80°C to +100°C

Write for complete brochure to:

APPLIED SCIENCE CORPORATION OF PRINCETON

P. O. BOX 44 PRINCETON, NEW JERSEY

CIRCLE 2 ON INQUIRY CARD

ELECTROMECHANICAL
components & systems **DESIGN**

STAFF

Publisher *H. G. Buchbinder*
Editor *R. B. Brotherston*
Comp. Digest Editor *Sidney A. Davis*
Associate Editor *Charlotte Kaizer*
Editorial Assistant *Lillian Greenberg*
Editorial Assistant *Theresa Sacks*

Staff Columnists *David Bandel, Renato Contini, Jesse E. Hobson, Israel Katz, Emile Labin, David A. Rich, Ronald C. Vickery, Martin Kagan, Herbert F. Spirer*

Contributing Editors *H. Donald Conway, Oliver Haywood, Joseph Hirsch, George King, William Seifert*

Art Director *James Flora*

Ass't. to Publisher *Ruth Robinson*

Dir. of Circulation *A. Allen Binder*
Director, Research *S. Henry Sacks*

Reader—Inquiry *Harry Kaizer, Gertrude Bandel, Carol Walton*
Administrative Ass't. *Theodore Nichols*

OFFICES

NEW ENGLAND *G. Palken*
1357 Washington St.
West Newton 65, Mass.
Bigelow 4-9006

NEW YORK CITY AREA *M. Berns*
21 East 63rd St.
New York 21, N.Y.
Templeton 8-4010

ATLANTIC STATES *L. Williams, R. Reimer*
Macintyre-Simpson & Woods
101 Park Avenue
Suite 1025
New York 17, N.Y.
Lexington 2-0020

CHICAGO *L. Woods, D. Sturgeon, A. Boz, D. Hascall*
Macintyre-Simpson & Woods
75 East Wacker Drive
Chicago 1, Illinois
Central 6-1715

CLEVELAND *L. Woods, D. Hascall*
Macintyre-Simpson & Woods
1900 Euclid Avenue
Cleveland 15, Ohio
Cherry 1-1501

WEST COAST *J. C. Galloway, J. Harbison*
6535 Wilshire Blvd.
Los Angeles, Calif.
Olive 3-3223

BPA

(Circulation for April 1959 is 26,054)

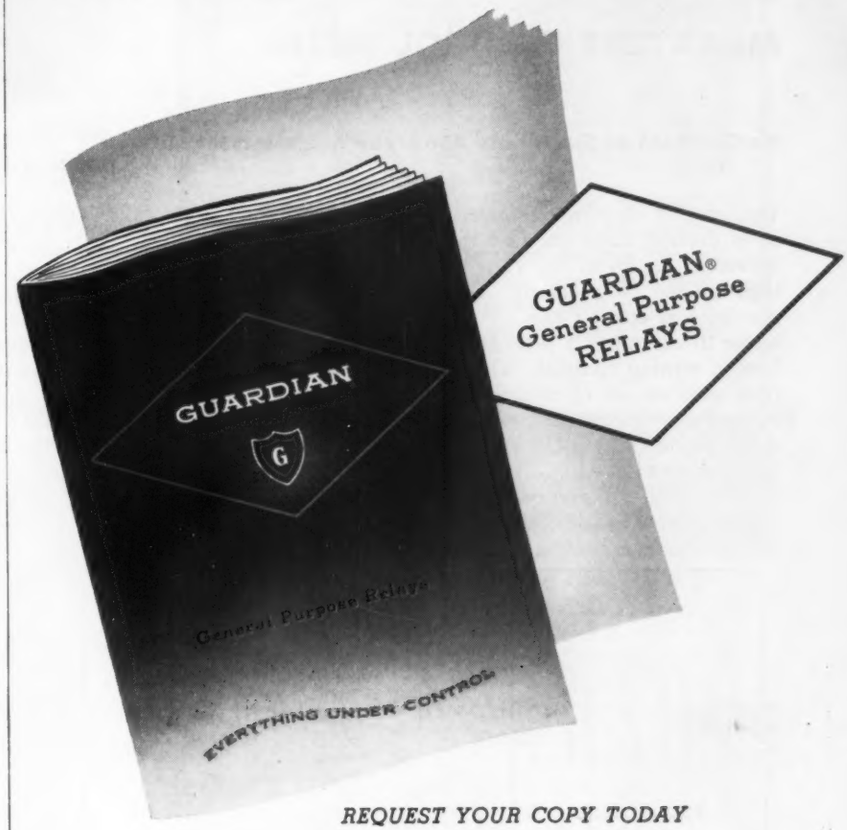
Published monthly by Benwill Publishing Corporation. Harold G. Buchbinder, President; Milton Berns, George Palken, Vice presidents, Robert M. Robbins, Treasurer. Executive, Editorial and Subscription Office 1357 Washington St., West Newton 65, Mass. Telephone BIgelow 4-9006. ELECTROMECHANICAL components & systems DESIGN is circulated without charge upon request to qualified research, development and design engineers in all branches of industry in the continental United States including governmental and university installations. Other subscriptions: Continental U.S., $10.00 per year; single copy, $1.00 when available. Copyright 1959 by Benwill Publishing Corporation. Accepted as controlled circulation publication at Orange, Conn.

Postmaster: send form 3579 to Benwill Publishing Corporation, 1357 Washington St., West Newton 65, Mass.

PRINTED AT THE WILSON H. LEE COMPANY, 440 BOSTON POST ROAD, ORANGE, CONNECTICUT

EVERYTHING UNDER CONTROL

PHOTOS • DRAWINGS • CAPACITIES • ENCLOSURES



REQUEST YOUR COPY TODAY

◆ A catalog you *must* not miss!
In it you will see a variety of Guardian *basic* General Purpose Relays, each associated with detailed dimensional drawings, available contact arrangements, current and coil operating data, terminal types, weights, enclosures, headers and mounting information. Individually, these *basic* relays afford unlimited variations to meet your *exact* specifications. Collectively, they tell the story of Guardian research—already responsible for so many major advances in relay development—your assurance of dependable control.

MIDGET • POWER • SENSITIVE • HEAVY DUTY • TIME DELAY

Write on your company letterhead for catalog "B"

GUARDIAN ELECTRIC
MANUFACTURING COMPANY

1641-D W. WALNUT STREET, CHICAGO 12, ILLINOIS
CIRCLE 7 ON INQUIRY CARD

MINIATURE CONTROL METER

No Contacts at Set Points Allow Full Scale Indication

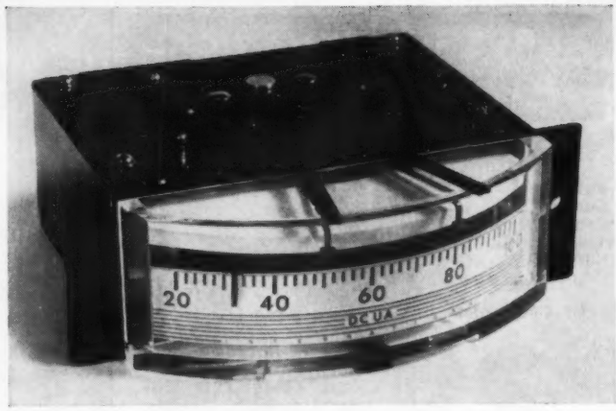


Fig. 1—International Instruments' Miniature Control Meter.

The idea of developing meter relays for controlling processes derived from the fact that a meter responds to and indicates signals in the very low microwatt region with a high degree of accuracy. By putting a contact on the pointer and one on the set point, designers adapted the meter to control of a process directly in response to signals from a sensing element. The high sensitivity of the meter relay avoided use of amplifiers which could not be depended on for linearity and tended to drift. Simplicity of meter relays made them preferable to null balancing control systems for many control applications where the latter are far too expensive and cumbersome.

But this original design of the meter relay—the non-locking type—had characteristics contributing to unreliability. Pointing out some of the problems in design of meter relays, Mr. John E. Hines, Jr., of International Instruments, Inc., New Haven, Conn. traces for us the evolution of reliable meter relay design and describes a new International Instruments control meter which he says is the next logical step in reliable design. First, he says, the pointer of the non-locking meter could not indicate past the control set point. This condition was not considered too serious. Secondly, insufficient pressure of the contacts, due to the low torque of the pointer arm, caused a high resistance path, resulting in sticking and welding of the contacts. Third, for high sensitivity movements, the electrostatic at-

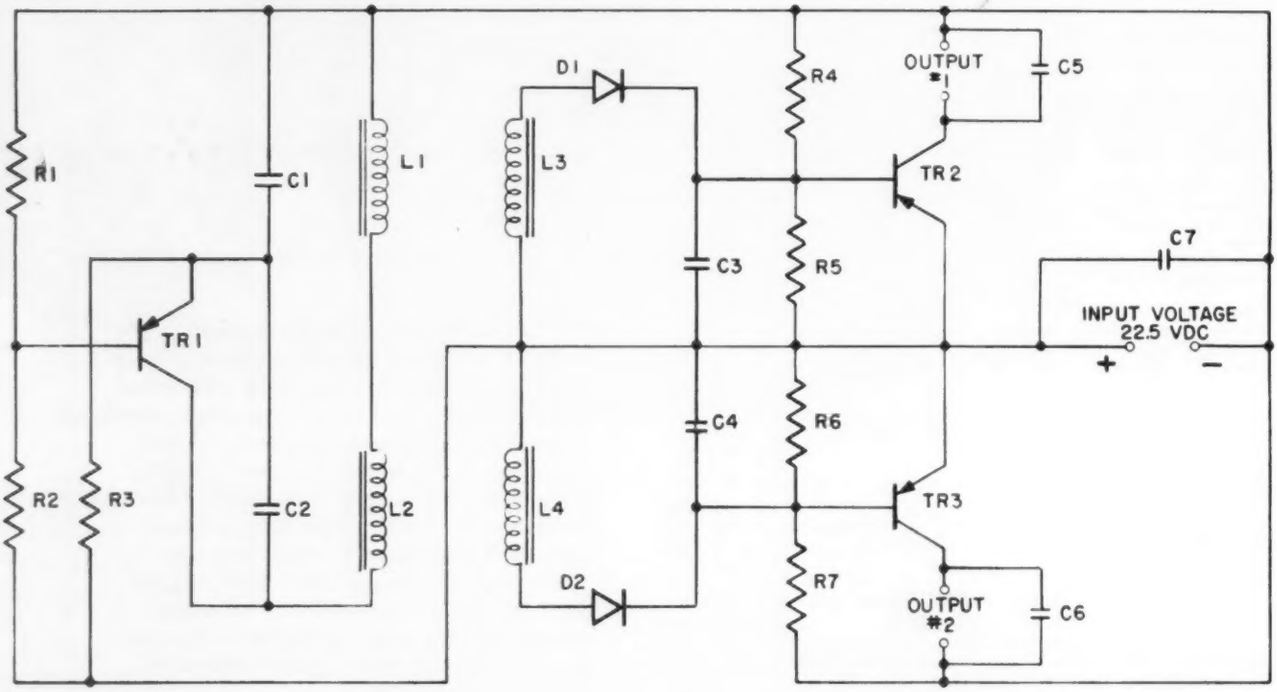


Fig. 3—Schematic of control meter circuit. The oscillator of the control meter is a typical Colpitts circuit with excellent linearity with input voltage. The oscillator coils couple their energy to the respective pick up coils. In the detector amplifier stage, the signal is picked up by coil L-3, rectified by diode D-1, filtered by capacitor C-3, and then establishes a positive polarity across the base, to the emitter of transistor TR-2. This would normally drive the transistor to cut off, but a negative polarity has already been established by the power supply and resistive network R-4 and R-5. R-4 is a value that will provide enough negative bias to buck the positive bias supplied by the coils, so that an output current of 1/10 of a milliampere will flow in the output load. This is the current flowing when the shield is not between the coils, and may be referred to as idle current. When the shield attached to the pointer passes between the coils, the amount of energy transferred to the pick up coil is decreased due to the shielding effect, and the positive bias all but disappears. The bias to the transistor is now strongly negative and the transisitor conducts heavily. An output of over two milliamperes flows through the output load, completing the switching action. If the shield passes out of the control area, the idle current returns. Capacitor C-7 prevents high frequency waves from entering the power supply. Capacitor C-5 and C-6 bypass any a-c component around the load so that almost pure d-c flows into the load.

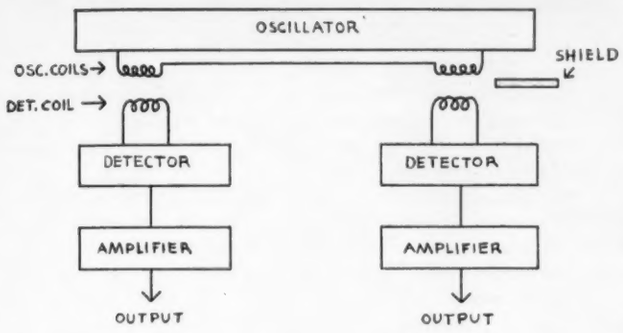


Fig. 2—Block diagram of the control meter circuit. The oscillator and the two control sections are independent of each other. As the metallic shield passes between either set of coils, that is, between an oscillator coil and a pick-up coil, it decreases the amount of energy transferred to the pick-up coil. This motion does not affect the oscillator in any way, yet initiates the control action. Since the oscillator is not affected, the energy to the second pick-up coil is not affected. Hence, more than one control is possible using only one oscillator. In conventional designs only one control point is possible per oscillator.

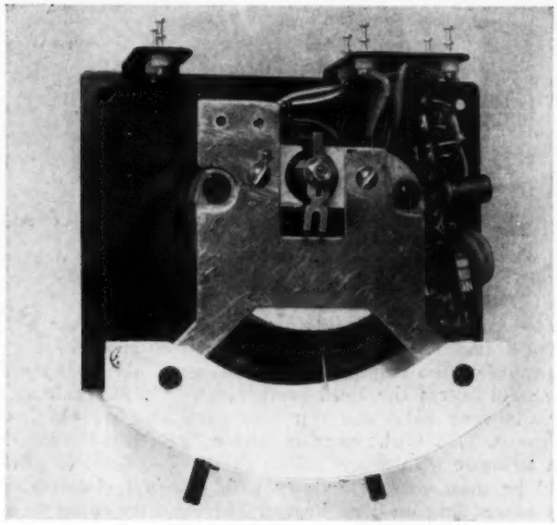


Fig. 4—Partially disassembled view of meter showing relative positions of circuit, movement, coils and pointer.

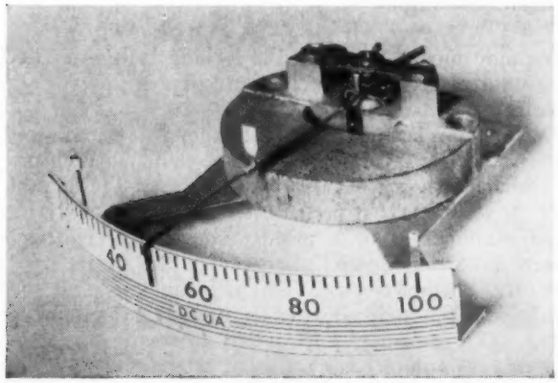


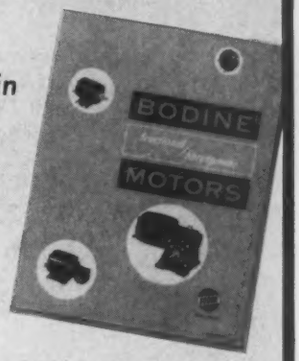
Fig. 5—Close look at coils and shield attached to pointer.

Continued on page 6

...for design engineers

Newly published bulletin covers

300 Stock BODINE MOTORS



FREE bulletin "S-1" . . . 12 pages of photos, cutaways, drawings, tables, and charts describe 300 different Bodine stock motors, (series wound, shunt wound, 3-phase, capacitor 3-lead, capacitor 4-lead, split phase, shaded pole . . . all in stock ready for prompt shipment). Ask for your copy.

BODINE fractional/horsepower MOTORS

...the power behind the leading products

Bodine Electric Co., 2516 West Bradley Place, Chicago, Ill.

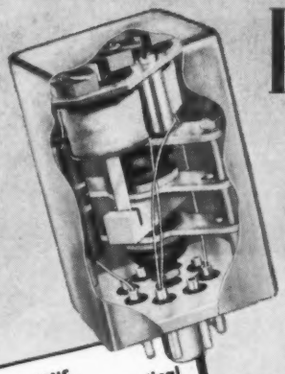
CIRCLE 8 ON INQUIRY CARD

FRAHM®

RESONANT REED

ROC

OSCILLATOR CONTROLS



APPLICATIONS
- Electrical and Acoustical Measurements
- Electrical Communication Systems (Selective Calling)
- Remote Operation and Supervisory Control of Machinery and Apparatus
- Electrical Computers and Telemetering Systems
- Electro-Mechanical Bandpass Filters

FEATURES
- High accuracy
- Stability of frequency control
- Self starting
- Infinite service life
- Integral, sealed, magnetically shielded
- Standard octal tube pin connectors
- Small, light weight

Write for BULLETIN 34-EMD

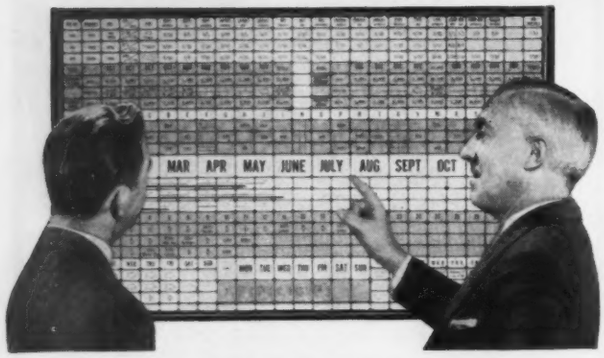
JAMES G. BIDDLE CO.

Electrical & Scientific Instruments

1316 ARCH STREET, PHILADELPHIA 7, PA.

CIRCLE 9 ON INQUIRY CARD

You Get Things Done Better By Seeing What's Happening



BOARDMASTER VISUAL CONTROL

- ★ Gives Graphic Picture of Your Operation in Color.
- ★ Facts at a Glance - Saves Time and Prevents Errors.
- ★ A Simple, Flexible Tool - Easily Adapted to Your Needs.
- ★ Easy to Use. Type or Write on Cards, Snap on Board.
- ★ Ideal for Production, Scheduling, Sales, Inventory, Etc.
- ★ Compact, Attractive. Made of Metal. 350,000 in Use.

Complete Price **$49.50** Including Cards

FREE 24-Page ILLUSTRATED BOOKLET AK-40 Without Obligation

GRAPHIC SYSTEMS, 55 West 42nd St., New York 36, N.Y.

CIRCLE 10 ON INQUIRY CARD

If you need a
DIELECTRIC PAPER,

MOSINEE

will make it to your
EXACT SPECIFICATIONS

for complete information write

MOSINEE
PAPER MILLS COMPANY
Mosinee, Wisconsin

CIRCLE 11 ON INQUIRY CARD

traction between the contacts pulled them in prematurely as the pointer contact approached the set point. This attraction varied with the voltage across the contact and its magnitude was appreciable.

Since high contact resistance was the prime source of trouble, some method of canceling this effect was necessary. One attempt was to permit only minute currents such as a microampere to flow across the contacts. To enable this current to control, devices such as "Thyratron" triggering circuits and transistor amplifiers were put into use. This minimized, but did not materially change, the original problem. Another method was to pull in the pointer by means of a magnetic force as it neared the control set point. This, for all practical purposes, eliminated the contact resistance problem, but introduced another—the magnetic attraction pulled in the pointer before it reached the trip point. To overcome this disadvantage, a locking coil was introduced. The locking coil replaced the magnetic locking features and eliminated premature pull-in. It is successfully used today. The locking coil is an extra coil wound on the coil frame

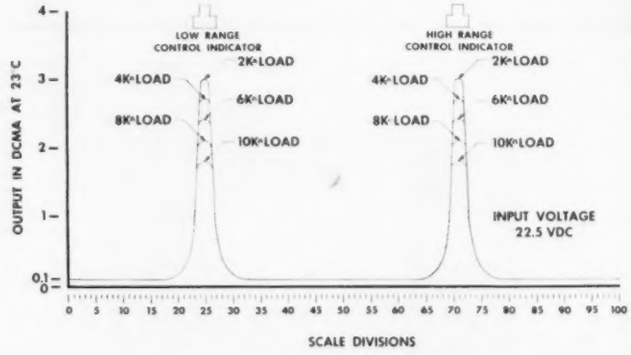


Fig. 6—Output versus scale divisions—illustrates the output as the shield enters and leaves a control area. Notice the broadness of the response at the base and the sharpness as the shield enters the field further. The control indicator is four divisions wide and represents the sharper portion of the curve. This is the portion where on/off type operations such as those with relays would occur. The broader portion could be used very effectively with external circuitry, possibly controlling an oven heater. The circuitry could be such that as the shield enters the field, power to the oven heater would decrease in direct proportion to the control meter output. Since this is almost exponential, a very smooth control of oven temperatures would be accomplished with this type of anticipating feature. Note how the value of the load has an affect on the output. The lower the load naturally the higher the output.

of the movement. Power to the locking coil is initiated at the instant of contact, thereby furnishing further torque to decrease contact resistance.

The meter relay just described, though superior to previous types, has its drawbacks. The first objection, as for the earlier units, is its inability to read past the control set point. A second is that premature pull-in on sensitive movements continues to be a problem because of electrostatic attraction. A new complication is that the circuit must be reset after contact closure. This is by far the most serious drawback. If a manual reset is used, an operator is required. The reset may be handled automatically, but only on a time sampling basis using an interrupter device, and involving additional expense for the accessory.

One final type of meter controller which enjoys wide ac-

Continued on page 8

Barden Precision SFRI-5 miniature bearings as used in a computer gear train.

Specify **BARDEN** *Precision miniature ball bearings*

Precision-built computer gear trains must have uniformly low torque and minimum backlash; mounting surfaces for the bearings should be simple to manufacture.

Barden Precision miniature-size bearings have the required low torque. Their low eccentricity and closely controlled radial play assure minimum backlash. Precision flanges provide accurate positioning surfaces and permit through-boring, eliminating the need for housing shoulders.

Barden Precision miniature bearings are built to the same high standards of consistent quality as Barden's larger instrument sizes.

Barden Precision means not only dimensional accuracy but performance to match the demands of the application.

Your product needs *Barden Precision* if it has critical requirements for accuracy, torque, vibration, temperature, or high speed. For less difficult applications, the *predictable* performance of *Barden Precision* bearings can cut your rejection rates and teardown costs.

Write today for your copy of Catalog Supplement M1 which gives dimensions, performance and engineering data on *Barden Precision* ball bearings 5/8" O.D. and smaller.

THE BARDEN CORPORATION

55 E. Franklin St., Danbury, Connecticut • Western office: 3850 Wilshire Blvd., Los Angeles 5, California

SPECIFY BARDEN PRECISION BALL BEARINGS FOR: INSTRUMENTS • AIRCRAFT ACCESSORIES • COMPUTERS AND RECORDERS • MACHINE TOOL AND TEXTILE SPINDLES • OTHER PRECISION APPLICATIONS

CIRCLE 12 ON INQUIRY CARD

ELECTRO-MEC'S *New*
DIGITOMETER™
(A Shaft Angle Digitalizer)

SHAFT POSITION TO NUMBERS
for record-indication or for computation.
NOW — A rugged shaft digitalizer
(non-ambiguous)
for AIRBORNE ENVIRONMENTS

NO GEARS • NO BACKLASH

TYPE 15
Diameter: 1.5"
Accuracy: 1 part in 256 parts for 360° of shaft rotation

TYPE 30
Diameter: 3.0"
Accuracy: 1 part in 1024 parts for 360° of shaft rotation

NO NON-AMBIGUITY NETWORKS

The system designer doing digital servo work recognizes the benefits of ELECTRO-MEC DIGITOMETERS because

1. Shaft position to electrical contact closures
2. No ambiguity (Gray Code)
3. Low shaft torque requirements
4. High slewing speed (650 rpm)
5. Small size
6. Lightweight
7. Designed to withstand the rigors of MIL (E) 5272 environmental test specification.

ELECTRO-MEC Laboratory, Inc.
47-51 33 Street, Long Island City 1, N. Y.

For data sheets or further information write to our Engineering Dept.

CIRCLE 13 ON INQUIRY CARD

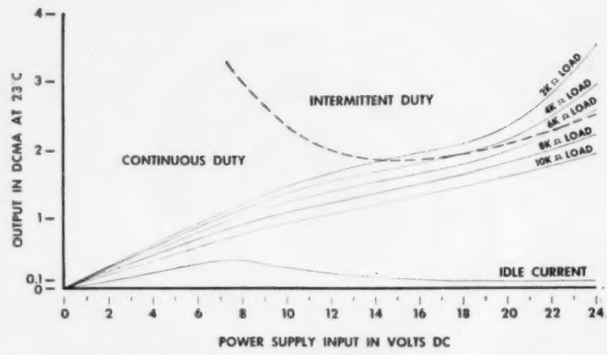


Fig. 7—Output versus power supply input for various loads —showing low and high conducting states as indicated by "idle" and "operate" conditions. Intermittent and continuous duty parameters are indicated. Idle current increases slightly with increasing input voltage, then returns to 1/10 of a milliampere along the portion from 15-24 volts. Recommended input voltage is 22½ volts. At this voltage notice the operating output of two milliamperes for an 8000 ohms load. This indicates a switching action possible, of from 1/10 to two milliamperes. Using a relay that pulls in at one milliampere, you could expect a snappy action from 18 to 24 volts. In terms of line voltage, the unit may be operated from 90 to 140 volts, easily a plus or minus 20 percent voltage spread from 115 volts. An intermittent duty line is indicated where, if the shield is held in the control area at the given voltages and load, an over-heating of the transistor takes place and thermal runaway is possible.

ceptance employs an electronic link rather than contacts, disposing of the contact problem most efficiently. It operates on the principal of a supersonic oscillation between two coils being disturbed by the passage between the coils of a metallic shield attached to the pointer of the meter. This design gives the advantages of:

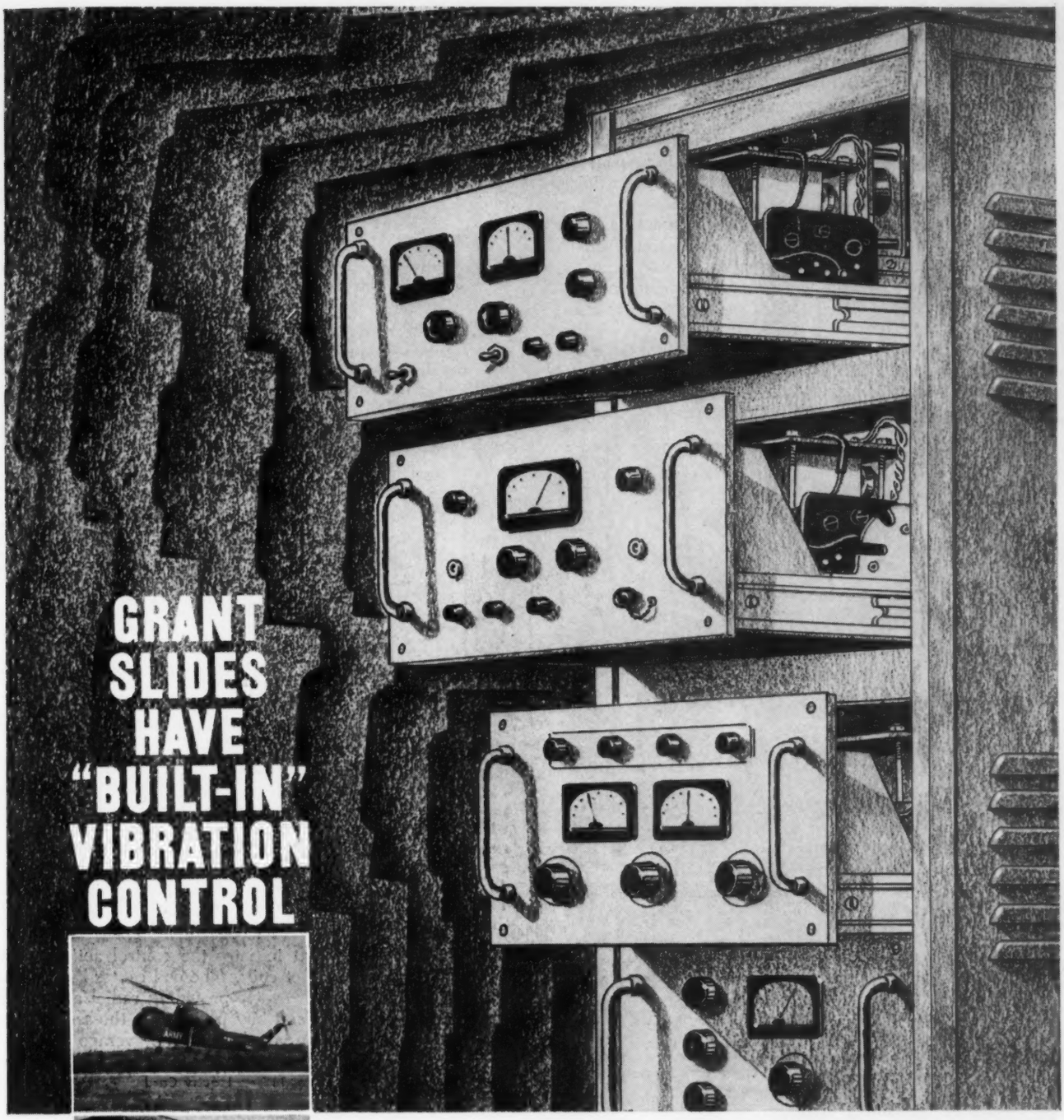
- Signal circuit and controlled circuit are independent.
- Linearity about the control point is characteristic with no premature pull-in nor reset effects.
- Full-scale indication of the meter is possible.
- No reset mechanism is required.

Mr. Hines says International Instruments' new control meter, Model 2545, represents the next logical forward step. The smallest control meter on the market, it has dual control arms, an entirely transistorized system in a unique circuitry based on the electronic link principal, and a pointer that can traverse the entire scale irrespective of the settings of the control arms.

In previous types of electronic link controllers, oscillation was obtained by means of a vacuum tube circuit. As the shield entered the control area, the oscillations were altered so as to close a relay in a specified type circuit. This function was reliable during the life of the tube, but it was necessary to wait for the tube filament to come to temperature before the unit could be operated.

In the new control meter circuit, the oscillation is not affected by the shield passing between the coils, and because the circuitry is transistorized, there is no waiting time for instrument warm-up. Figure 1 is a photograph of the complete meter, showing the dual control arms which may be set at any point on the scale. Figure 2 describes the operation of the circuit, and Fig. 3 is the circuit schematic. The relative positions of the circuitry movement, coils and pointer are shown in Fig. 4, and Fig. 5 gives a closer look at the coils and the shield attached to the point-

Continued on page 10



From the aluminum extrusions, to the stainless steel balls, the patented "ball retainer" the exclusive "Shok-Loks" and the precision **assembling and fitting,** Grant Slides are constructed with an absolute maximum of strength and serviceability. Pilot windows on the Sikorsky helicopters are mounted on Grant Slides — which operate continuously well under the most severe vibratory conditions.

We'll be pleased to send you your complete Grant Catalogue.

The nation's first and leading manufacturer of slides

GRANT INDUSTRIAL SLIDES

GRANT PULLEY AND HARDWARE CORPORATION / *85 High Street, West Nyack, New York*
944 Long Beach Avenue, Los Angeles 21, Cal.

CIRCLE 14 ON INQUIRY CARD

Bristol miniature pressure switch

features ultra-reliable precision pressure element. Exclusive design provides outstanding resistance to shock, vibration, acceleration and overpressures.

These Bristol miniatures, widely proved in modern aircraft, are designed for switching electrical circuits in response to pressure changes in air, fuels, lubricants, hydraulic fluids, other gases and liquids.

Bristol's specially designed Ni-Span element is silver brazed to the stainless steel base assuring greater reliability than ordinary soft-soldered construction. Result: accurate, reliable, repeatable performance in any position, at temperatures from —65° F to +250° F, and under Mil Spec environmental requirements.

Write for Bulletin AV2010 on Bristol Miniature Gage and Absolute, Adjustable and Differential Switches. The Bristol Company, Aircraft Components Division, 175 Bristol Road, Waterbury 20, Conn. 8 44

SPECIFICATIONS (Fixed pressure setting models)

Normal Working Range — 0 to 100 psi absolute, gage, or differential

Burst Pressure — exceeds 250% of normal working pressure

Electrical Ratings — 5 amp at 125 v, 60 cycle, inductive or resistive
4 amp at 30 vdc resistive
2.5 amp at 30 vdc inductive

Dielectric Strength — 500 v rms between terminals and from terminals to case (MIL-S-8801)

Life at Rated Electrical Load — 40,000 cycles at 125 vac
25,000 cycles at 28 vdc

High Temperature Exposure & Operating — (MIL-S-8801) 250° F

Low Temperature Exposure & Operating — (MIL-S-8801) —65° F

Shock, 30 g, 3 axes — (MIL-S-8801) no change

Vibration — (MIL-S-8801) no contact chatter, no switch damage
300-600 cpm at 0.050" d.a.—set point change—none
operating differential change—none
600-4500 cpm at 0.036" d.a.—set point change—¼ psi
operating differential change—½ psi
4500-30,000 cpm at 10 g—set point change—¼ psi
operating differential change—½ psi

Diameter—1-5/16

BRISTOL FINE PRECISION INSTRUMENTS FOR OVER 69 YEARS

CIRCLE 15 ON INQUIRY CARD

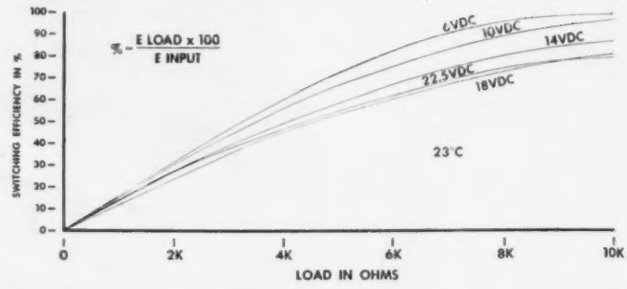


Fig. 8—Switching efficiency versus load for various voltages. For optimum conditions the higher values of the load are the best choice. The circuitry was streamlined for an 8000 ohm sensitive relay. The higher percent efficiencies indicate that the power available is present in the load with very little in the transistor. Power is wasted in the transistor with lower efficiencies.

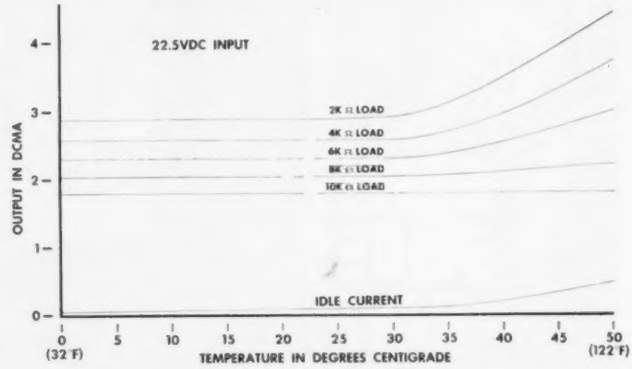


Fig. 9—Output versus temperature for 22½ volts—showing that output will remain constant over the temperature range with higher resistance loads, but will increase with temperature for lower resistance loads. From 0 to 50 degrees centigrade at 10,000 ohms there is no change in output current. As the load decreases in value, undesirable changes occur. The idle current rises slightly at 50 degrees centigrade but this is not considered detrimental.

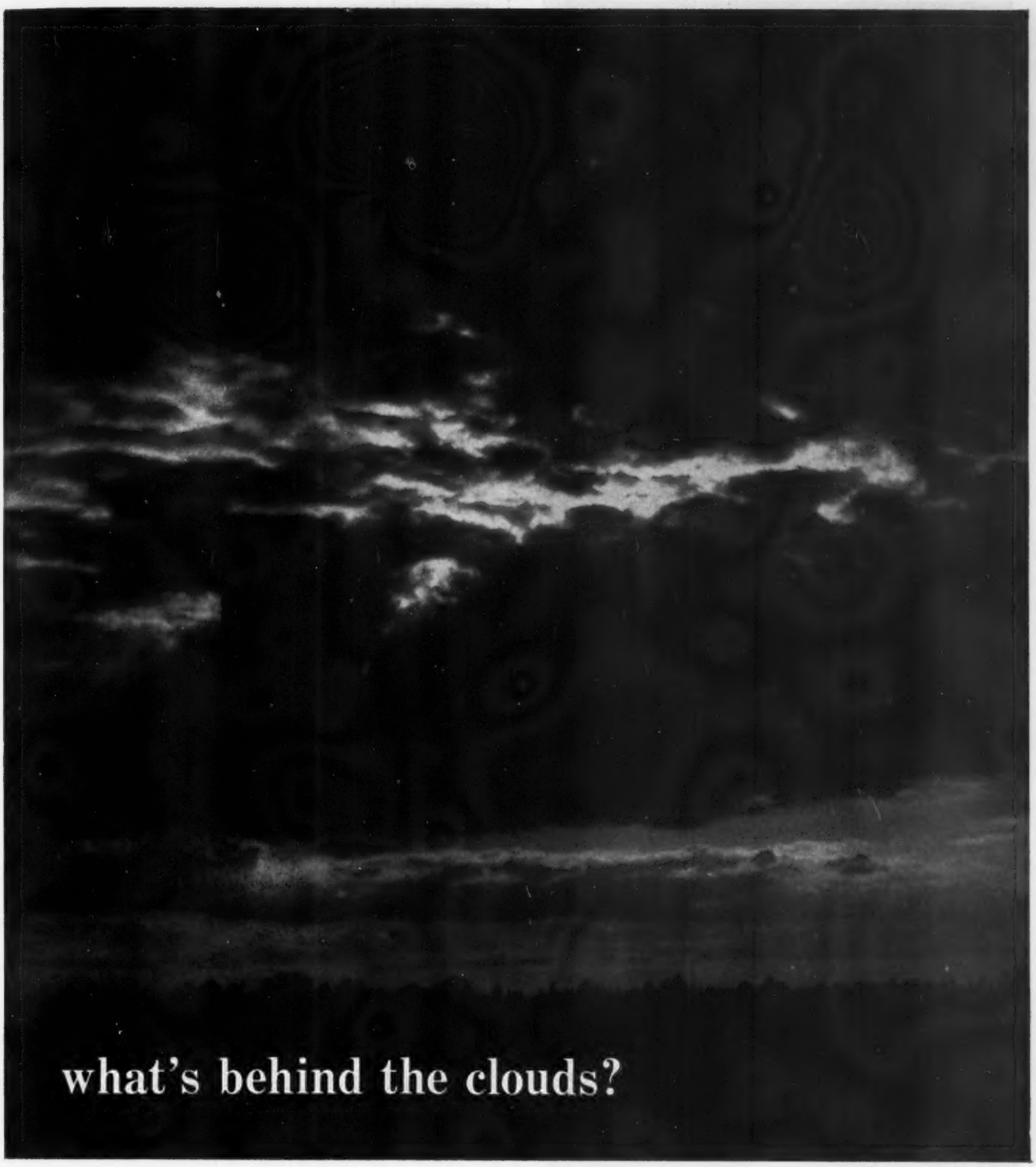
er. It is this shield that initiates the control action, as it passes through each set of coils. The coil center line passes through the movement's center providing radial alignment of the shield to the coils at any position on the scale. Figures 6, 7, 8 and 9 are curves showing the average performance characteristics of the meter.

Circle No. 117 on Inquiry Card

Silicon Zener Regulator Diodes

A new complement of silicon zener regulator diodes are available in four nominal basic power ratings: Series B, 750 milliwatts; Series T, 1 watt; Series G, 3.5 watts; and Series K, 10 watts; the first two in an axial pigtail top hat package and the higher power devices in 10-32 stud-mounted cases. The fabrication and packaging techniques used in their manufacture result in a stable, reproducible regulator which will withstand severe environments. Carefully controlled characteristics of these components may be used in a variety of circuits in such applications as power supply voltage regulators, meter protectors, go-no-go indicators, clippers, bias controls, filament voltage controls and voltage references. Zener breakdown voltage ranges cover from 3.6 volts to 30 volts in each power rating. I.T.&T., Components Div., Clifton, New Jersey.

Circle No. 171 on Inquiry Card



BEHIND THE CLOUDS hides a cunning enemy with ever-improving weapons to threaten our security. To deter these airborne aggressors is the job of the all-weather interceptor, our first line of defense.

Partaking in a giant chess game, a Hughes Airborne Systems Engineer is constantly fed intelligence information regarding the most recent enemy advances. He asks the question, "How effective are present interceptors against the new enemy capabilities, and how can we counter this challenge?"

The Hughes Airborne Systems Engineer is concerned with the design of hardware, but he does not design hardware. He is more interested in the broader systems aspects. Taking an analytical approach, he must solve the interacting problems of performance, reliability, maintainability, and operability.

If this type of systems engineering interests you, investigate the assignments now open in:

SYSTEMS ANALYSIS • SYSTEMS EVALUATION
SYSTEMS DESIGN • SYSTEMS FLIGHT TEST
SYSTEMS DESIGN CO-ORDINATION

The salary structure for these positions reflects the advanced nature of the assignments. Please inquire by writing directly to Dr. Allen Puckett, Director, Hughes Systems Development Laboratories.

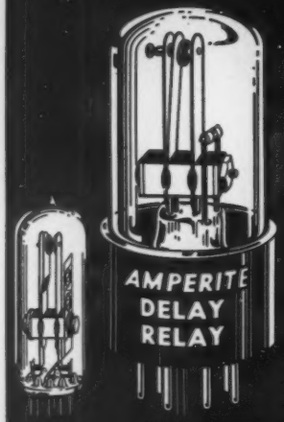
HUGHES AIRCRAFT COMPANY
CULVER CITY 13, CALIF.

HUGHES

©1958, HUGHES AIRCRAFT COMPANY

AMPERITE PREFERRED

by design engineers—because they're
MOST COMPACT • MOST ECONOMICAL
SIMPLEST • HERMETICALLY SEALED



Thermostatic DELAY RELAYS

2 to 180 Seconds

Actuated by a heater, they operate on A.C., D.C., or Pulsating Current.

Hermetically sealed. Not affected by altitude, moisture, or climate changes.

SPST only—normally open or closed.

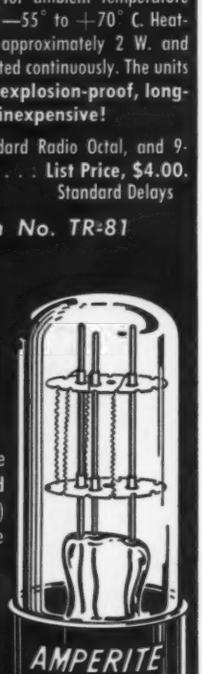
Compensated for ambient temperature changes from —55° to +70° C. Heaters consume approximately 2 W. and may be operated continuously. The units are **rugged, explosion-proof, long-lived,** and—**inexpensive!**

Also — **Amperite Differential Relays:** Used for automatic overload, under-voltage or under-current protection.

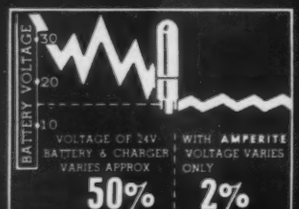
TYPES: Standard Radio Octal, and 9-Pin Miniature . . . **List Price, $4.00.** Standard Delays

PROBLEM? Send for Bulletin No. TR-81

BALLAST REGULATORS



Amperite Regulators are designed to keep the current in a circuit **automatically regulated** at a definite value (for example, 0.5 amp.) . . . For currents of 60 ma. to 5 amps. Operate on A.C., D.C., or Pulsating Current.



Hermetically sealed, they are not affected by changes in altitude, ambient temperature (—55° to +90° C.), or humidity . . . Rugged, light, compact, most inexpensive . . . . . **List Price, $3.00.**

Write for 4-page Technical Bulletin No. AB-51

AMPERITE CO. Inc., 561 Broadway, New York 12, N. Y.
Telephone: CAnal 6-1446
In Canada: Atlas Radio Corp., Ltd., 50 Wingold Ave., Toronto 10

CIRCLE 16 ON INQUIRY CARD

COMPONENTS DESIGN

SILICON PNPN CONTROLLED SWITCH

A Step Beyond the Transistor

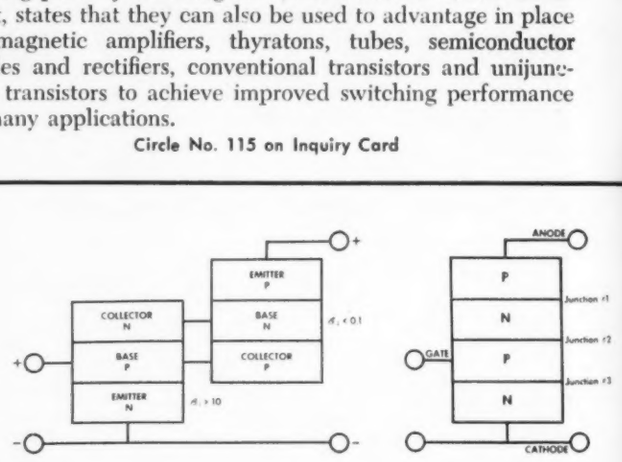
Developed by Solid State Products, Inc. of Salem, Mass. these new switches are now in pilot line production. Their 3A series, in the JETEC TO-9 package, has voltage ratings to 200 volts and peak current ratings to 1 ampere. Turn on time in the region of 0.2 microseconds is typical. High gain-high speed-medium power switching, beyond that possible with present day transistors, can now be achieved.

Typical current gains of 500 and power gains of 250,000 are possible at output peak current levels as high as 1000 ma. This compares to current gains of 50 and power gains of 2500 with today's silicon transistors. In addition, the PNPN switch requires only an instantaneous input pulse to switch and stay "on". Transistors, on the other hand, require continuous input. Because of their unique properties, the PNPN controlled switches open many applications.

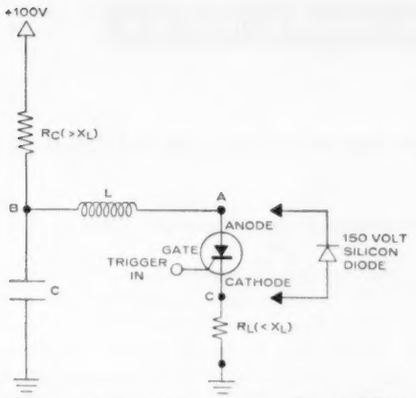
Some of the many possible applications include: magnetic core switching, flip flops, logic circuitry, pulse generation and shaping, inverters, motor controls, regulated power supplies, servo systems and high level demodulators, and particularly a.c. static switching and control circuits.

Within their ratings, these new semiconductor switches will replace mechanical switching devices such as relays and vibrators with the advantages of reduced size and no moving parts. J. B. Hangstefer, Solid State Products' President, states that they can also be used to advantage in place of magnetic amplifiers, thyratons, tubes, semiconductor diodes and rectifiers, conventional transistors and unijunction transistors to achieve improved switching performance in many applications.

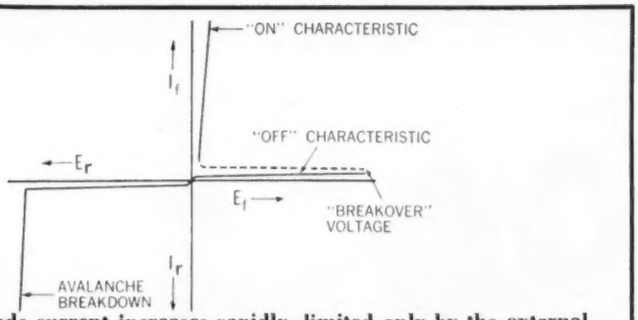
Circle No. 115 on Inquiry Card



Operation of the PNPN Switch can best be explained by considering the analogy of two transistors: a high gain NPN unit and a low gain PNP unit. In this configuration the collector current of the NPN unit feeds the base of the PNP, and the collector current of the PNP feeds the base of the NPN. This arrangement gives a positive feedback loop and when the product B_1 B_2 reaches unity, the system is self-regenerative. With the base of the NPN transistor (gate) reverse biased, only a small leakage current flows from cathode to anode. (Junction #2 is biased in the reverse direction.) At this low current level, B_1 and B_2 are relatively low and their product is less than unity. This is the "off" condition of the forward characteristic and the device has a very high impedance. When a small forward bias current is applied to the base of the NPN transistor (gate), anode current (collector current of the two transistors) rises, causing an increase in B_1 and B_2. As the anode current rises to a critical minimum value, the product B_1 B_2 reaches unity and the system becomes self-regenerative. When this occurs, the



Circuit diagram above shows how the PNPN controlled switch can generate high current half sinusoid or full sinusoid pulses in magnetic core switching. With the controlled switch "off", capacitor C charges through R_c so that the potential at points "B" and "A" is 100 volts. When a positive trigger pulse is applied to the gate of the controlled switch it "fires", becoming essentially a short circuit. C discharges resonantly through L and load R_L. If the PNPN controlled switch were to remain "on", a damped train of sinusoidal oscillations occurs at a frequency determined by L and C. However, after the first half sinusoid of current flow, the PNPN switch goes into the reverse direction and becomes non-conducting, leaving the potential at "B" and "A" at almost —100 volts (depending on the amount of circuit damping). C then charges slowly back to +100 volts, completing the cycle. The circuit can be made self-triggering by deriving the trigger current from the potential at "B". A silicon diode connected between points "A" and "C" will conduct when the PNPN switch goes into the reverse direction. This diode passes a negative half sinusoid of current so that current through R_L is a full sinusoid. C is resonantly recharged and the potential at "B" returns toward +100 volts much more rapidly than by the relatively slow process of charging through R_c. If the diode is connected between point "A" and ground, resonant recharging current bypasses R_L, so that only the positive half sinusoid current pulse passes through R_L.



anode current increases rapidly, limited only by the external load. Once the regenerative action has started, the externally applied gate current no longer affects the system and it may be removed. This is the "on" condition of the forward characteristic and the device has a very low impedance. To turn the switch "off" once it has "fired", the anode current must be reduced to below the sustaining or "holding current" level. The PNPN switch will also "fire" from "off" to "on", with no external gate current, when the anode voltage, positive with respect to the cathode, exceeds a value called the "breakover voltage". This occurs because the current flow through the switch rises above the critical value at which the product of the two current gains reaches unity. When an anode voltage, negative with respect to the cathode is applied, Junctions #1 and #3 (emitter to base junction of the two transistor elements) are biased in the reverse direction. The switch has a high impedance under this condition and behaves essentially the same as a conventional silicon diode in the reverse direction.

Electromechanical Engineers

attending the

Southwestern I.R.E. Regional Conference

and

Electronics Show

April 16-18

experienced in

INERTIAL NAVIGATION SYSTEMS

AIRBORNE TACTICAL DATA SYSTEMS

AIRBORNE COMPUTER SYSTEMS

Contact the representative of our Electronic Equipments Division, Mr. C. T. Petrie, at the Baker Hotel, RIverside 8-1471.

Work in advanced electronics at Litton Industries, which includes design and production of complete systems for military and commercial use, offers extraordinary scope for electromechanical imagination.

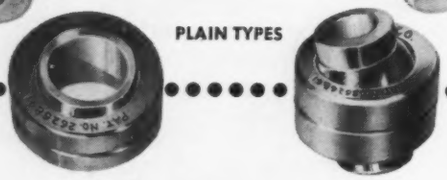
LITTON INDUSTRIES
Electronic Equipments Division
Beverly Hills, California

SOUTHWEST
"Monoball"®
SELF-ALIGNING
BEARINGS

ROD END
TYPES

PATENTED U.S.A.
All World Rights Reserved

PLAIN TYPES



CHARACTERISTICS

	ANALYSIS	RECOMMENDED USE
1	Stainless Steel Ball and Race	For types operating under high temperature (800-1200 degrees F.).
2	Chrome Alloy Steel Ball and Race	For types operating under high radial ultimate loads (3000-893,000 lbs.).
3	Bronze Race and Chrome Steel Ball	For types operating under normal loads with minimum friction requirements.

Thousands in use. Backed by years of service life. Wide variety of Plain Types in bore sizes 3/16" to 6" Dia. Rod end types in similar size range with externally or internally threaded shanks. Our Engineers welcome an opportunity of studying individual requirements and prescribing a type or types which will serve under your demanding conditions. Southwest can design special types to fit individual specifications. As a result of thorough study of different operating conditions, various steel alloys have been used to meet specific needs. Write for Engineering Manual No. 551. Address Dept. EMD-59

SOUTHWEST PRODUCTS CO.
1705 SO. MOUNTAIN AVE., MONROVIA, CALIFORNIA

CIRCLE 17 ON INQUIRY CARD

POWER TRANSMISSION PROGRESS

I. Maintenance-Free Magnetic Clutch

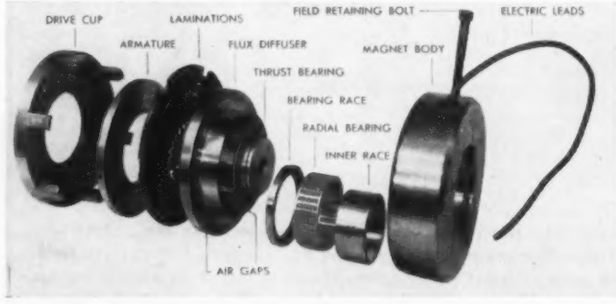
A novel stationary-field magnetic clutch virtually eliminates the need for maintenance in machine transmissions. I-T-E Circuit Breaker Company, Philadelphia, designers of the new clutch, states that they also permit reductions in the size of machine tool transmissions by providing more torque for their size than any other units commercially available.

These clutches can be buried in a machine drive box or transmission and forgotten because there are no air gap adjustments to be made, no slip rings and brushes to be cleaned, adjusted or replaced. The new design, incorporating a closed flux path through hardened steel laminations, eliminates the need for adjusting air gaps. Use of a stationary magnetic field—coil windings are on the stator instead of on the rotor—eliminates slip rings and brushes.

Developed after more than three years of experimentation with 27 different designs, company engineers claim that clutches provide a new concept in trouble-free, dependable control for virtually any type of transmission requiring clutches.

Largest imediate application for the clutches is in the machine tool field, for such jobs as speed-changing, feed drives, brakes and couplings in drive systems of lathes, boring mills, planers, milling machines and grinders. However, these new clutches open up many new possibilities for use in drive systems of a wide range of other equipment: machines for such jobs as washing, pulverizing, printing, packaging and strapping and more specialized equipment such as conveyors, welders, wind tunnels, nuclear control mechanisms, radar antennas, test equipment and steel rolling mills.

The new clutch series, designated EC-S, includes five sizes with torque ratings ranging from 14 through 290

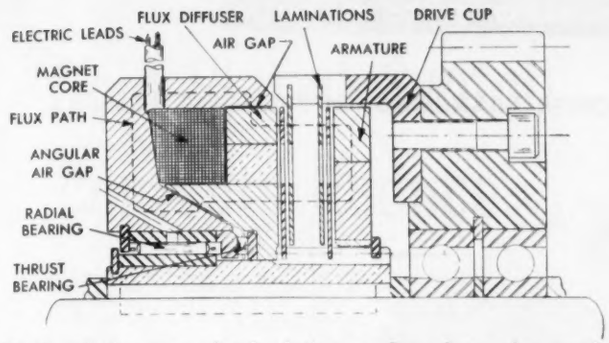


A primary advantage of the new clutch is single-unit construction. Simplifying machine assembly, it permits fast installation. The stationary portion of the clutch is secured from rotation by a single threaded rod which screws into a tapped hole in the magnet body.

pound-feet. Here are their design, construction and performance features:

- Unique, long-life bearing design.
- Low-inertia design for minimum flywheel effect.
- Multiple control voltages available.
- Ease of adaptability through use of an external drive cup.

Though the stationery-field concept eliminates the problems created by slip rings and brushes on conventional



Much of the new clutch design evolves from the special consideration given to thrust loads. In designing the clutch, I-T-E did not seek to eliminate the loads caused by stray flux (resulting from high flux densities necessary in any magnetic clutch.) Instead, the company designed a longer air-gap—shaped like a cone—which was oriented approximately 30 degrees relative to the shaft axis. In so doing, thrust load on the roller thrust bearing was reduced appreciably by converting a portion of it to bear against a radial needle bearing. Also, by enlarging the air-gap cross-sectional area, flux density across the gap was reduced. This, in turn, reduced the number of ampere-turns required to produce enough flux for proper pressure on laminations.

clutches, it brings up a new one—that of high-thrust loads on support bearings. Bearings of all stationary-field clutches must withstand heavy thrust and radial loads because of the high flux densities across the air gaps.

Because space available for bearings is far less than that needed for ball bearings that could handle the load, I-T-E employed roller thrust bearings—the type used with great success in automobile transmissions.

Open construction of the clutch provides a two-fold advantage: Oil can enter around the radial bearing and the angular-split air-gap acts like a pump to flush the bearing area and dissipate heat developed in the coil. Rotating elements of the clutch have been kept to a minimum to reduce overall inertia so that flywheel effect of the clutch on the transmission is negligible.

All stationary-field clutches in a drive system can be connected electrically at a central terminal block. Each clutch receives power through a 30-inch, 18-gauge stranded neoprene-coated wire connected to the magnet body. Electrical connections can conform to JIC specifications.

Circle No. 113 on Inquiry Card

II. Packaged Electric Clutch and Sheave Simplifies No-Load Starting

Electro-Sheave, a combined electric clutch and sheave assembly for direct installation on all standard NEMA electric motor shafts permits equipment builders and industrial users to take advantage of electric no-load starting without the engineering, machining and assembly costs usually required to adapt standard electric clutches to primary shafts. Designed by Warner Electric Brake & Clutch Co., Beloit, Wisconsin, Electro-Sheaves engage or release at any speed. For inching or jogging several starts are possible in less than one revolution of the clutch without what is considered normal wear and tear on motors, controls or machinery. Release is instantaneous and the load is braked without plugging the motor.

Only a key and setscrew are required to install the unit in addition to making electrical connections to the clutch and brushholder from the control panel. Because the entire clutch and sheave is aligned and assembled correctly at the factory, engineering time and machining for adapting it to a particular installation are eliminated.

Continued on page 16

NEW!
DYNACO STOCK DIFFERENTIALS
MINIATURE HOLLOW SHAFT
IMMEDIATE DELIVERY STOCK PRICES
1/16 & 1/8"
Shown 2 times actual size
DIFFERENTIALS
STAINLESS STEEL
HOLLOW SHAFT • FACE GEAR • END GEAR
Cat. #HSD559-4 shown for mounting on .062" shaft, (4) ABEC 1 ball bearings, clearance dia. 0.580", displacement 15° arc.
FREE!
Send for Supplement "C" of E88 Dynaco Catalog
See us at the Design Engineering Show—Booth 404
DYNAMIC GEAR CO. INC.
20 Merrick Road
Amityville, N.Y.

CIRCLE 18 ON INQUIRY CARD

MORE DESIGN FREEDOM
accurate motion
transfer without complicated gearing...
SIERRA MINIATURE MECHANICAL CHAIN AND SPROCKETS...
Provide precise, positive motion transfer through several planes simultaneously with no cable slippage...no complicated gearing. Unlimited center-to-center selection for miniature and sub-miniature assemblies in servo systems, gyro systems, special cameras, electronic equipment, and small precision instruments. Less weight, cost, maintenance—wider tolerances. Designed to operate around minimum 7-tooth sprocket with root diameter of .250 inches. Chain pitch .1475 inches; Weight .45 oz. per lineal ft. Material: stainless steel, or other materials, including non-magnetic beryllium copper.
NEW CATALOG
Contains useful application data, specifications, tables on chain pitch and sprocket sizes, suggestions for calculating center-to-center distance. *Write for yours today.*
123 E. Montecito Avenue, Sierra Madre, California
Sierra ENGINEERING CO.
T. M. REG.

CIRCLE 19 ON INQUIRY CARD

sinusoidal AC from DC

with

Sineverter*

** a truly unique transistorized power source offering, for the first time, clean sine-wave power from any d-c source without bulky filtering.*

INPUT VOLTAGE:	**Up to 50 volts DC**
OUTPUT VOLTAGE:	**As required**
OUTPUT FREQUENCY:	**50 to 1500 cps as required**
TOTAL HARMONIC CONTENT:	**Normally less than 5%, 1% if desired**
REGULATION:	**±2% or less for normal line changes. 2% no load to full load.**
FREQUENCY STABILITY:	**Normally ±1%.**
POWER OUTPUT:	**Up to 1 kva**

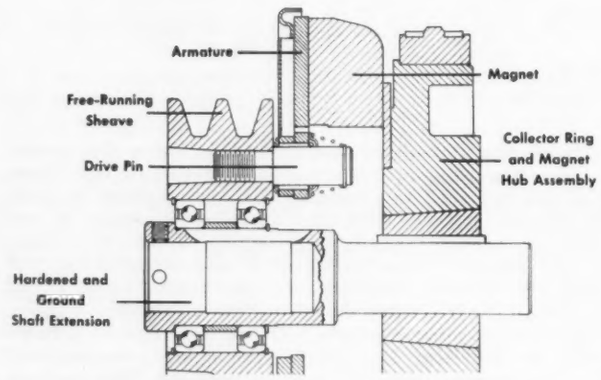
IMPORTANT: Sineverters are open- and short-circuit stable. In contrast with some inverters, a Sineverter cannot be damaged by open or short circuits and is immediately operative upon removal of an output short. . . . Yet output wave shape, voltage, and frequency are unaffected by load variations within ratings.

Write today for further details.

Specify POWER SOURCES BY
POWER SOURCES, INC.
Burlington, Massachusetts

CIRCLE 20 ON INQUIRY CARD

POWER TRANSMISSION PROGRESS (Cont'd.)



The clutch, ball-bearing sheave and shaft extension sleeve all fit as a single package onto standard NEMA motor shafts. Actuation of the clutch field attracts and locks the armature, which picks up motor rotation and transmits it to the pulley. When the clutch is disengaged, the sheave runs freely on anti-friction bearings. There is no mechanical connection between motor shaft and sheave, so no torque is transmitted from one to the other. Positive lock-in of the magnet and armature permits controlled no-load starting. Full engagement of the clutch is possible in milliseconds. Another advantage of electromagnetic operation is that it permits smooth, precise inching control, utilizing the flywheel effect of the motor rotor to help make several fast starts in only a fraction of a revolution. This method of jogging power transmissions minimizes wear on motors, controls and machinery.

Because the motor runs continuously, the inertia of the motor rotor and clutch magnet aids the motor. The breakdown torque of the motor is available for starting the load, permitting a smaller motor to be used in many applications. On installations that would ordinarily require frequent starting and stopping of the motor, the elimination of high-motor starting currents permits the use of smaller, less expensive starters. Also because it isn't necessary to stop the high iertia motor rotor, stops are faster and smoother. Smaller clutches can often be used because they are applied to the motor shaft rather than to a slower secondary shaft.

A rheostat in the control panel can be adjusted to increase torque buildup time, matching the starting torque to load requirements. The electric clutch will not slip at normal operating speeds; yet, the rheostat feature permits exact synchronization of the controlled function with other machinery and reduces shock load on gear, belts and materials in process. Direct electrical control and operation of the clutch facilitates the use of pushbuttons, relays and other automatic devices. The new drive simplifies interlocking of machinery to prevent damage.

Circle No. 114 on Inquiry Card

WORTH FILING

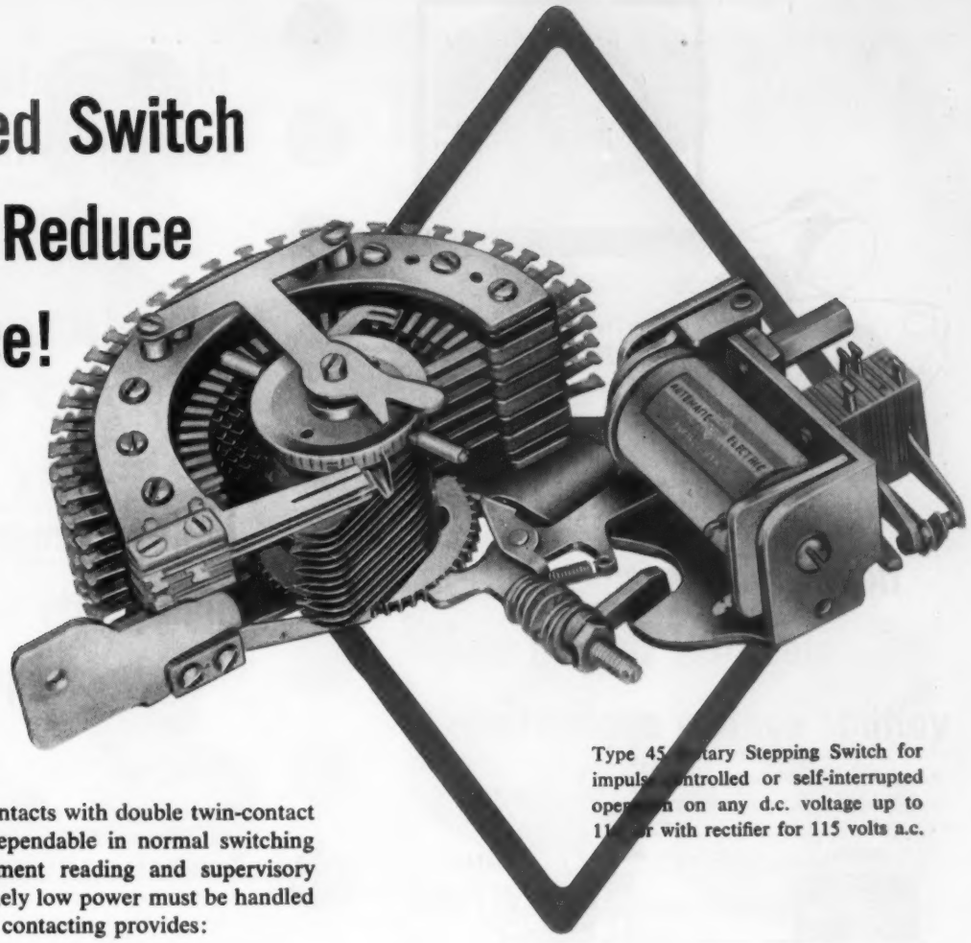
Quick Selector Chart

A quick selector chart simplifies the selection and ordering of motor controls. It includes motor control ratings, sizes, features, catalog numbers and ordering instructions.

Source: Arrow-Hart & Hegeman Electric Co.
Hartford, Conn.

For your copy: Circle No. 154 on Inquiry Card

Gold-Plated Switch Contacts Reduce Resistance!



Type 45 ...tary Stepping Switch for impuls... ...ntrolled or self-interrupted oper... ...n on any d.c. voltage up to 11... ...r with rectifier for 115 volts a.c.

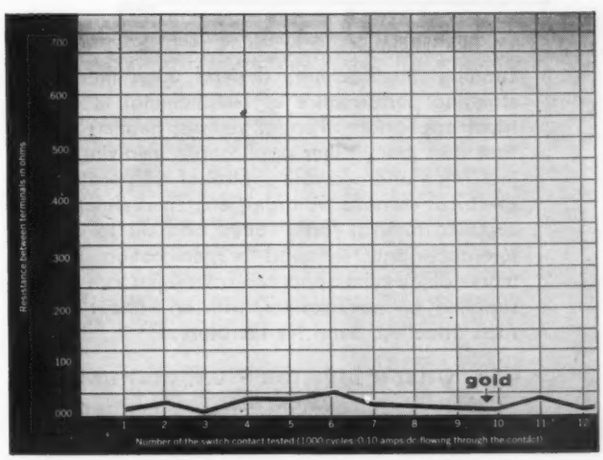
Standard base-metal contacts with double twin-contact design are absolutely dependable in normal switching circuits. But in instrument reading and supervisory functions, where extremely low power must be handled reliably, precious-metal contacting provides:

- *accuracy at lowest potentials*
- *low and constant contact resistance for the life of the switch*
- *freedom from spurious potentials which can be set up by base-metal contacts*

That is why instrument engineers specify gold-plated contacts for thermocouple monitoring and other low-power-level circuits – strain gauges – computers – and infrequently operated devices.

Precious-metal contacting costs more, of course. But with Automatic Electric's custom designing, it is not as expensive as you might think; on either Type 44 or Type 45 Switches, you can specify precious-metal contacts for instrument circuits only, with standard contacts handling the less critical circuits.

For full information on the use of stepping switches—*with or without* precious-metal contacts—ask for Circulars 1641 and 1698. Write: Automatic Electric Sales Corporation, Northlake, Illinois. *In Canada:* Automatic Electric Sales (Canada) Ltd., Toronto. *Offices in principal cities.*

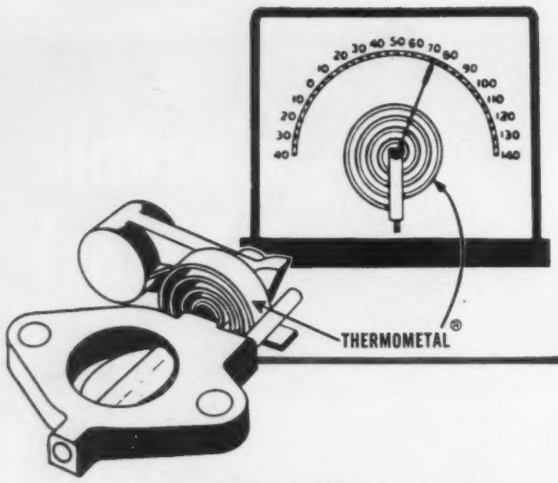


Graph indicates resistances between terminals with gold-plated contacts. Measurements made under heavy vibration.

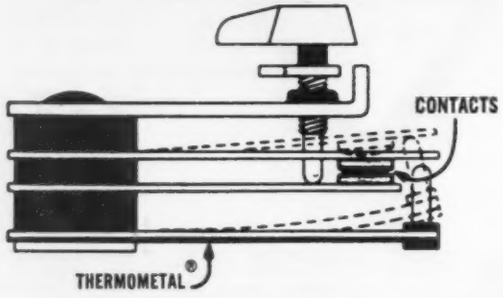
AUTOMATIC ELECTRIC

Northlake, Illinois • Subsidiary of GENERAL TELEPHONE

CIRCLE 21 ON INQUIRY CARD



THERMOMETAL® for dependable temperature, electrical current and voltage control applications



Leading manufacturers depend upon the outstanding performance of Thermometal in electrical appliances, thermal cutouts, heating controls and many other applications involving the indication and accurate control of temperatures, electrical currents, voltages, etc. Thermometal is supplied in strip form, rolled and slit to close tolerances and tempered to specification. Thermometal elements and sub-assemblies are also supplied to specifications, with or without contacts attached. Send for literature.

H. A. WILSON DIVISION • U.S. HIGHWAY 22 UNION, N. J.

look to Amersil for all high purity fused quartz requirements.

Amersil manufactures and fabricates high purity fused quartz for ultraviolet transmission applications, laboratory ware and production equipment. These products include standard apparatus, plain tubing in many intricate fabrications, crucibles, trays, cylindrical containers and piping in a full range of sizes up to 25" in diameter. Ingots and plates are available in general commercial quality as well as in special optical grades. Amersil engineers are also prepared to assist in developing fused quartz and silica equipment for special requirements. Send for bulletin.

AMERSIL QUARTZ DIVISION • 685 RAMSEY AVENUE HILLSIDE, N. J.

H. A. WILSON DIVISION

WRITE FOR LITERATURE

AMERSIL QUARTZ DIVISION

DOMESTIC DIVISIONS: AMERICAN PLATINUM & SILVER DIVISION, AMERSIL QUARTZ DIVISION, BAKER CONTACT DIVISION, BAKER DENTAL DIVISION, BAKER SETTING DIVISION, BAKER PLATINUM DIVISION, CHEMICAL DIVISION, EAST NEWARK INDUSTRIAL CENTER, HANOVIA LAMP DIVISION, HANOVIA LIQUID GOLD DIVISION, IRVINGTON-BAKER REFINING DIVISION, D. E. MAKEPEACE DIVISION, NATIONAL ELECTRIC INSTRUMENT DIVISION, RESEARCH AND DEVELOPMENT DIVISION, H. A. WILSON DIVISION. COMPANIES ABROAD: ENGELHARD INDUSTRIES OF CANADA, LTD. TORONTO, ENGELHARD INDUSTRIES OF QUEBEC, LTD. MONTREAL, ENGELHARD INDUSTRIES, LTD. LONDON, ENGELHARD INDUSTRIES A. G. ZURICH, ENGELHARD INDUSTRIES PTY., LTD. MELBOURNE, SOCIEDAD SURAMERICANA DE METALES PRECIOSOS S. A. BOGOTA, INDUSTRIE ENGELHARD S. P. A. ROME, ENGELHARD INDUSTRIES OF SOUTHERN AFRICA, LTD. JOHANNESBURG. ASSOCIATED COMPANIES: ACME TIMBER INDUSTRIES LTD., SOUTH AFRICAN FOREST INVESTMENTS LTD., SOUTH AFRICA, AZOPLATE CORPORATION, CHARLES ENGELHARD, INC., NUCLEAR CORP. OF AMERICA, INC., U.S.A.

CIRCLE 22 ON INQUIRY CARD

CIRCLE 23 ON INQUIRY CARD

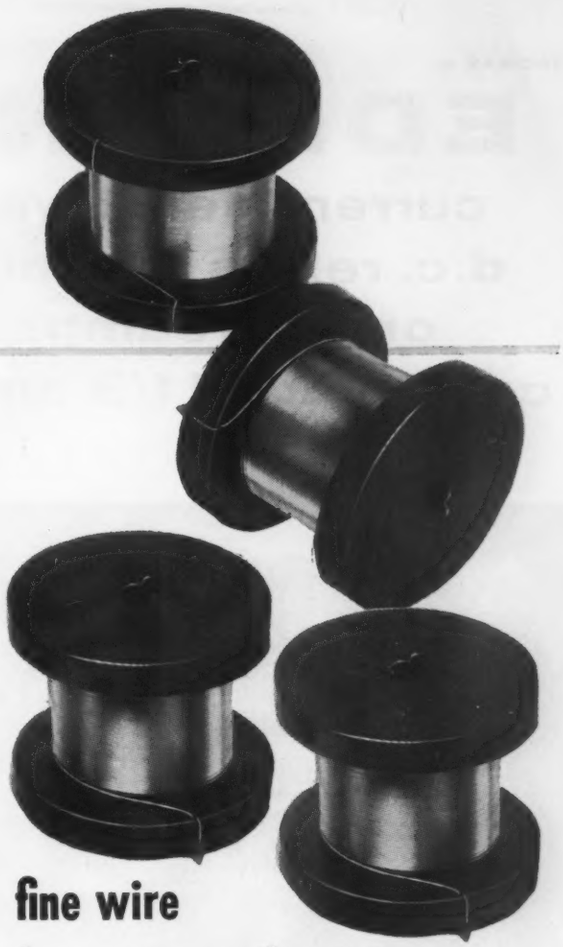
a simplified mirror-bright silver plating process

Here is the most efficient, simple procedure to protect electrical electronic and lamp components with a mirror-bright silver finish—through a complete range from flash to heavy deposit. The procedure is easy, economical and non-critical—with little or no polishing required. Silva-Brite is a clear, water-white solution, enabling the operator to observe work as it is being plated. Uniformly good results are attained with current densities ranging from 10 to 40 amperes per square foot. Normal room temperature operation minimizes fumes and tendency toward bath decomposition. Send for descriptive data together with detailed plating procedures.

AMERICAN PLATINUM & SILVER DIVISION
231 N. J. RAILROAD AVENUE, NEWARK, N. J.

AMERICAN PLATINUM & SILVER DIVISION

fine wire for every application



Here, you will find a thoroughly dependable source for fine wire of ductile and non-ductile materials for every application. Special processes have been developed for bare drawing wire as fine as .0004". Where smaller fine wire is required, the Wollaston Process for ductile metals and the Taylor and Extrusion methods for non-ductile materials are employed. All standard fine wire requirements are stocked for prompt delivery. Full facilities are available for the production of fine wires made to your own specifications.

BAKER PLATINUM DIVISION • 113 ASTOR STREET
NEWARK, N. J.

BAKER PLATINUM DIVISION

ENGELHARD INDUSTRIES, INC.

EXECUTIVE OFFICES:

113 ASTOR STREET • NEWARK 2, NEW JERSEY

CIRCLE 24 ON INQUIRY CARD

CIRCLE 25 ON INQUIRY CARD

THOMAS A.

EDISON

current sensitive d.c. relays operate on microamps... carry load of 1/3 amp

This meter-type relay is capable of operating on an input power of 25 microwatts—and on even less power in special applications. When the relay is factory-adjusted for the special conditions to be encountered, sensitivities down to 1 microwatt are possible.

Edison sensitive relays can replace a vacuum tube amplifier in many applications, and offer important savings in weight and cost. Because of their low operating power level, they can be run directly from a thermocouple or photocell output—and are ideal for uses involving servo motors operating from vacuum tube plate circuits. Between the input power to the operating coils and the load capacity of its own contacts, these relays make possible a power amplification factor in excess of 500,000 to 1.

For complete data on Edison Sensitive Relays, write for Bulletin No. 3037.

Thomas A. Edison Industries
INSTRUMENT DIVISION

68 LAKESIDE AVENUE, WEST ORANGE, N. J.

EDISON ENGINEERING OFFICES ARE LOCATED IN: CHICAGO; DALLAS, DAYTON, LOS ANGELES

CIRCLE 26 ON INQUIRY CARD

PRINTED CIRCUIT MOTORS

Flat, Light Disk-Shaped Armature Contains No Iron

Recent development of two-sided printed circuit boards with reliable plated-through holes makes the cost, quality and engineering advantages inherent in printed circuitry available for d-c motor design. The new technique is being applied to designs of printed circuit armatures, containing no iron, to replace the conventional wound armature (Fig. 1). In fractional horsepower sizes, d-c motors with printed circuit armatures have a wide field of applications in servomechanisms, paper and magnetic-tape transports, intermittent motions devices, and in data processing equipment. The general advantages of the printed circuit motor are listed in Table I. American patent applications in all types of printed machines and their components are held in the U. S. A. by Printed Motors, Inc., New York, N. Y. Photocircuits Corporation, of Glen Cove, N. Y., has developed the printed circuit techniques for the motor parts.

Figures 2 and 3 show the relation of the armature disk to the rest of the machine in a typical small motor design. Note the use of an axial rather than the conventional radial magnetic field, and the application of brushes directly to the bare armature conductors rather than to a commutator. While at first glance it may appear that the large air-gap, which comprises the thickness of the printed armature plus the sum of two clearance gaps, limits output and efficiency, the excellent coercive force of modern magnetic materials as well as the almost ideal cooling from the large exposed areas of the printed conductors permit ratings comparable to those of motors of more conventional design. Use of glass or ceramic composition for the armature provides excellent high temperature characteristics.

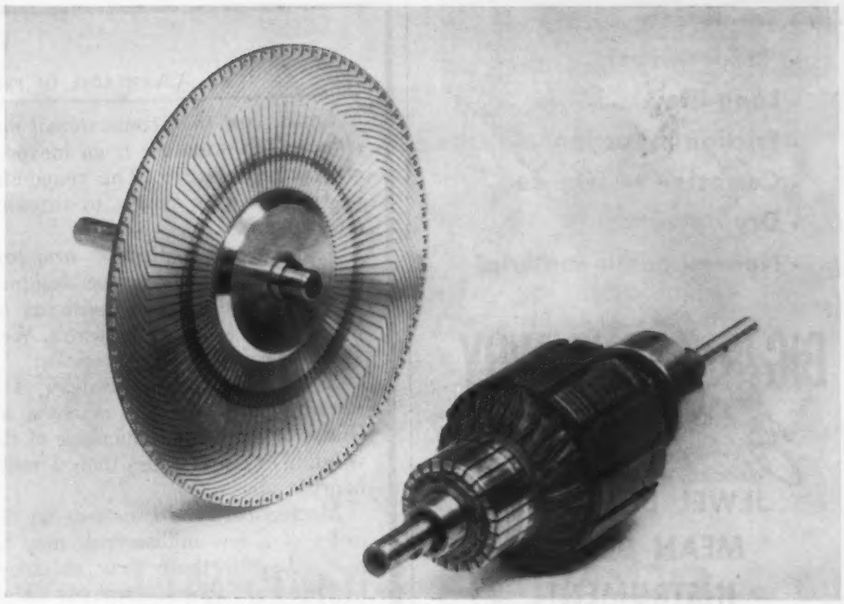


Fig. 1 Comparison of a d-c motor armature made in the conventional manner with one made by printed circuit techniques. The printed circuit unit is not only a flat, light disk weighing ⅛ that of the conventional unit but contains no error and is automatically mass produced without hand soldering operations. Flat ribbon-like copper conductors are printed on each face of the disk. The curved portions of the conductor near the edge and center of the disk are connected to corresponding sections on the opposite face by Photocircuits Tuf-plate plated-through holes. This entire group of conductors constitute the printed-circuit equivalent of a multi-polar wave winding in conventional machines. Many types of windings are possible.

SERVOMECHANISM APPLICATIONS

The printed circuit motor is especially suited to d-c servo applications for the following reasons:

1. The absence of rotating iron improves commutation, reducing sparking and radio interference, and providing longer life.
2. The large number of "commutator segments" means smooth operation, even at low speeds.
3. The absence of the slotted iron armature eliminates magnetic cogging, providing improved sensitivity to small control errors.

continued on page 22

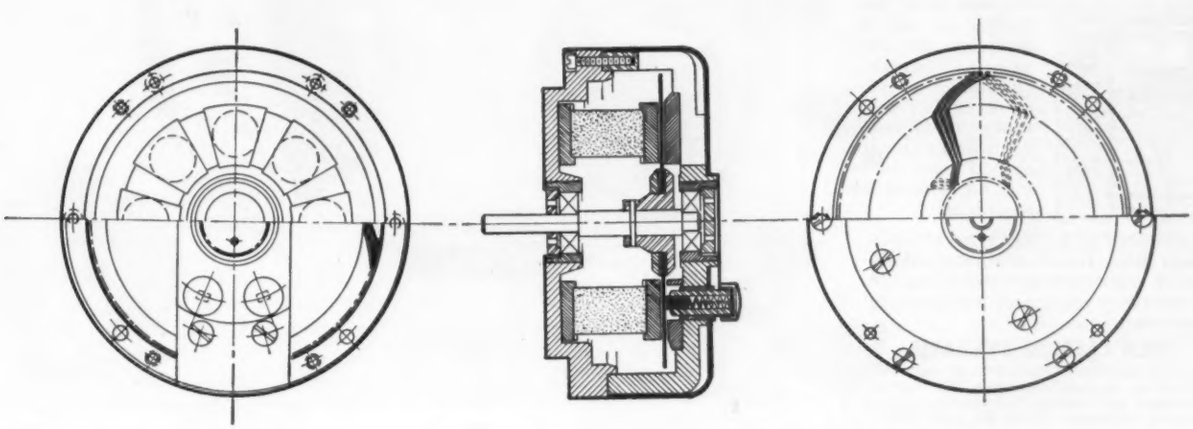


Fig. 2 Schematic view of a printed circuit direct current machine, shows the relation of the armature disk to the rest of the machine in a typical small motor design. Note that the flat armature is cooled by thermal conduction to the hub and thermal radiation to adjacent pole pieces. Small area temperature measurements have shown that the differential between the rotating disk and the pole pieces is on the order 5°F under steady-state conditions. Base materials for the printed windings may consist of glass or other ceramic composition, making the armature virtually unaffected by heat. The large surface areas of the printed armature permits current densities up to 30 or 40 amperes per square millimeter in continuous operation, and up to 100 amperes per sq. millimeter in intermittent operation.

- Small size
- Reduced cost
- Long life
- Friction reduction
- Corrosion resistance
- Dry operation
- Non-magnetic material

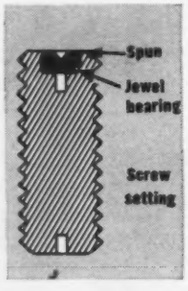
BIG REASONS WHY

Bird PRECISION JEWEL BEARINGS MEAN BETTER INSTRUMENT PERFORMANCE

In today's miniaturized instrumentation Bird Sapphire and Glass Jewel Bearings show their unique properties to best advantage . . . dry operation through temperature extremes . . . resistance to corrosion fumes and liquids . . . adaptability to special mounting arrangements.

Bird Complete Jewel Assemblies

. . . save time and money, cut rejects, keep production flowing smoothly. Special mounting techniques provide assemblies in screws or bushings of any style.



Bird Cushion Jewel Assemblies

. . . add shock protection to any instrument for only pennies. Variable cushioning of silicone rubber controls movement, eliminates waste due to poor bearing adjustment in mounting.

Compared with other types of bearings Bird Jewels are substantially more economical and their long life expectancy eliminates maintenance problems.

NEW CATALOG AVAILABLE

. . . a complete description of properties and uses of jewel bearings for aircraft, electrical and timing instruments, recorders and indicators. Write for your copy.

Richard H. Bird & CO., INC.
1 Spruce Street, Waltham, Mass.
Serving Industry With Fine Jewels Since 1913

CIRCLE 27 ON INQUIRY CARD

TABLE 1

ADVANTAGES OF PRINTED CIRCUIT D-C MOTORS

Lower cost than conventional machines: The armature is an inexpensive printed circuit. The remainder of the motor is simple to machine and assemble.

Extremely low intrinsic armature inertia: Machines may be designed with mechanical time constants on the order of a few milliseconds. Well suited for direct drive in servos.

Small armature inductance: The rotating portion of the machine includes no iron; the inductance of the winding is usually less than 1 millihenry.

Mechanical time constants on the order of a few milliseconds may be realized with these new machines because of their extremely high speed response.

Extremely smooth commutation: Due to a large number of commutator segments, low armature reaction, the form of the armature windings, that there is no iron to rotate, the torque is completely free from cogging at any speed.

High temperature operation: All active armature conductors are uninsulated, and the flat form of the machine leads to excellent cooling of the windings.

Possibility for internal damping: For special applications the machines may be furnished with an internal damping torque proportional to speed.

Wide horsepower range: Shaft output power may range from a few watts to several kilowatts.

Low internal impedance: The machines are ideally suited for operation with power transistors.

Planar air gap construction: Mechanical form factor lends itself to "pancake" shapes.

4. Internal damping is achieved simply by using a conducting disc as the printed circuit base. Aluminum, for example, rotating in the permanent magnet field will provide excellent damping while adding little inertia. The conductivity of the base material determines the amount of damping.

5. Low armature inductance does not add a significant electrical time constant to the dominant mechanical time constant, which means improved stability for a given loop gain.

6. The high torque to inertia ratio, combined with additional internal damping provides very low mechanical time constants which means wide-band highly stable servo performance.

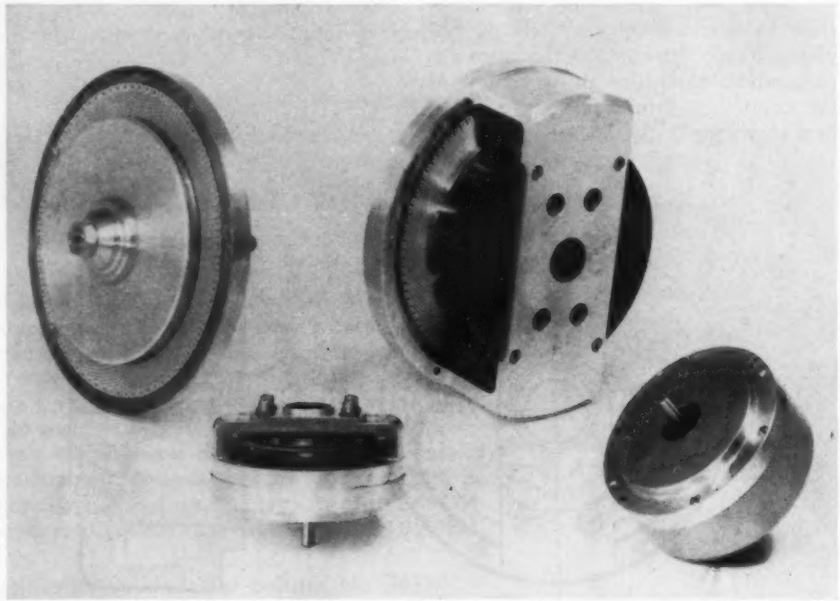


Fig. 3 The printed circuit armature is mounted in a planetary air-gap machine so that the straight radial portions of each conductor lie within the field flux. Magnetic circuit shown in the larger unit is an 8-pole structure excited by Alnico-6 permanent magnets. The arrangement is typical of printed circuit machines since it makes possible the most efficient use of the flat armature winding. Six or ten poles are equally feasible; six is the most economical. Advantages of the multipole field may be kept in small sized machines.

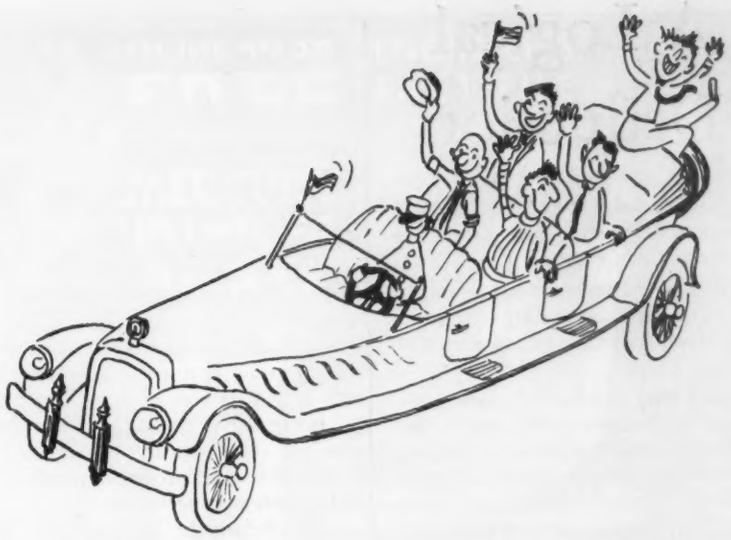
For certain instrument and servo system applications direct coupling is desirable because it reduces cost and improves performance by eliminating backlash. But the inertia of the load from the point of view of the motor shaft is greatly increased and good viscous damping is required to provide stable operation. This may be easily accomplished in printed circuit machines by replacing the insulating core of the armature winding with a conductive one, such as aluminum. Eddy current will then provide braking torque proportional to speed. In a typical machine, this torque is 5 ounce-inches per 100 rpm. The useful output will be absorbed by the viscous damping at about 160 rpm without reducing the available starting torque.

The time required for such a damped machine to respond to an input signal may be extremely small if the proper choice of the damping factor and associated electrical circuitry is carefully made. As described above, the armature windings may be formed directly over the aluminum core so that inductive coupling between winding and core is high. Under these conditions, the armature inductance, and therefore the electrical time constant of the armature, becomes essentially zero. Since the input impedance of the machine is then resistive, a large value of armature current and corresponding torque may be established effectively in phase with a step-wave voltage drive from a simple electrical driving system such as a power transistor. Solution of the equations of motion for a damped machine shows that the mechanical time constant is inversely proportional to the magnitude of the viscous damping. These two effects have been combined in the design of a servo motor having a stall torque of 60 inch-ounces and a mechanical time constant of 4 milliseconds.

In servo system and tape transport applications, this motor will respond to driving frequencies as high as 100 cycles. The designers claim it is the only d-c motor that combines a high starting torque capability with wide frequency response.

Smooth torque and absence of any preferred armature position provides excellent angular definition in accurate servo systems.

Errors due to load friction, a problem in the absence of gearing, may be reduced by employing a high gain servo-amplifier. This is possible only where the dynamic characteristics of the motor and the absence of gear back lash preclude instability. High stall torques (unaffected by adding damping) assist in reduction of friction errors.

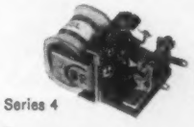
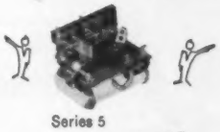
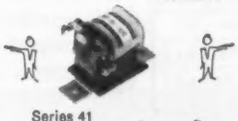


UNSUNG HEROES

We wish we could afford a newer automobile with an emblazoned banner for *each* of these gentlemen*, to tell the whole relay-using world of their accomplishments. For these are the souls who design that seldom-heralded product—the plebeian Sigma relay. Unlike more renowned Sigma engineers, they can never go home at night and say "Today I built a relay that will make history"; instead, their efforts will only keep someone's juke box, remote-controlled toy, electric blanket or burglar alarm working.

Here are five of their achievements that are about as experienced as relays can be; the "4", "5" and "41" have proved themselves since early WW II days, the others almost as long. Being old standbys also means they're for sale and deliverable in quantity.

* Perhaps you recognize the man on the spare tire as Mackinaw L. Mundane of April 1958 fame.

AC		DC
	 Series 4	Rugged, lightweight general-purpose SPDT design with adjustable pull-on and drop-out. Standard sensitivity 20 or 50 mw., rated 2 amperes resistive for 100,000 operations.
Built-in rectifiers. Operation comparable to DC performance, except for coil overload capacity and speed.	 Series 5	Dual coils, SPDT, sensitivities from 1 mw. to 2 watts. High stability and shock resistance. Available adjustments include precision DC, close differential, meter protection, break-delay, etc.
Shaded pole version, for 60 cycle positive ON-OFF operation only. Standard sensitivity 0.3 volt-ampere. Type 11F — 1⅛" x 1⅛" x 1" high, wt. 1 oz. max.	Series 11	Small, low cost ($1.50-2.45) SPDT relay. Ideal for remote control units for toys and TV sets, door openers, etc. Mechanical life 100,000,000 operations. Four mtg. styles, unenclosed only.
Shaded pole SPDT design. Sensitivity 0.06 to 0.40 volt-ampere, 60 cps (specials for 16-400 cps.) Long life; quiet, inexpensive. Ratings up to 5 amperes resistive.	 Series 41	DC sensitivities 40 to 200 mw. Fast, bounce-free switching; useful for keying; speeds to 100 pps. Shock and constant acceleration up to 100 g will not cause damage.
DPDT version of Series 41, but with 0.30 and 0.50 volt-ampere standard sensitivities. Standard frequency 60 cps, specials 16-400 cps. Contacts rated 2 or 5 amperes. Economical of power.	Series 42	DPDT version of Series 41, but with 100 and 200 mw. standard sensitivities. Can serve as output relay of many electronic controls; often used where UL approval is required. Contacts rated 2 or 5 amperes.

Bulletins on any of these Series on request.

SIGMA

SIGMA INSTRUMENTS, INC.
32 Pearl St., So. Braintree 85, Mass.
AN AFFILIATE OF THE FISHER-PIERCE CO. (Since 1938)

CIRCLE 28 ON INQUIRY CARD

A Logical Deduction

Because the design of an NJE SOLID STATE transistorized power supply permits **no compromise with quality;**

Because every transformer and choke is a **MIL-T-27-A** style unit; every resistor is **wire-wound;** every capacitor is the **finest** of its type;

Because every component is significantly derated at the **worst combination** of line, load, and ambient conditions, including repeated short circuits and critical partial overloads;

Because NJE "regulation" is the **total** of the **worst simultaneous combination** of line and load effects, static and dynamic;

Because NJE circuitry provides **stability,** against both time and temperature, **better than the rated regulation;**

Because we build all 14 standard models from three mass-produced "building blocks", **very competitively,** despite higher quality,

It follows that your best buy in a transistorized power supply is NJE SOLID STATE.

QED... choose NJE

SS-32-20,
rear view,
showing swing-out panel.

MODEL	VOLTS	AMP.	MODEL	VOLTS	AMP.
SS-7-15	0-7	0-15	TR-36-1	0-36	0-1
SS-10-10	0-10	0-10	SS-1603	0-160	0-1.5
SS-10-50	0-10	0-50	SS-1605	0-160	0-3.0
TR-18-2	0-18	0-2	SS-3600	10-36	0-50
SS-32-3	0-32	0-3	SS-1503	100-150	0-1.5
SS-32-10	0-32	0-10	SS-3003	200-300	0-1.5
SS-32-20	0-32	0-20	SS-1505	100-150	0-3.0

NJE CORPORATION

345 Carnegie Avenue, Kenilworth, New Jersey
CH 1-1500 TWX - Roselle, N. J. 51 FAX - FFP

CIRCLE 3 ON INQUIRY CARD

APPLICATION NOTES

The printed armature opens the door to a large variety of general purpose and special purpose motors. The possibilities for further development seem vast. Micro-miniature versions, disk shaped machines installed directly on printed circuit boards, perhaps driving low torque film potentiometers, point the way to a sort of *layer* construction of many servo packages, i.e., motor + damper + gearhead + potentiometer. Limitations and problems requiring further study appear to be

(1) Relatively low voltage driving signals for miniature units due to the limited number of printed conductors compared to the number possible in a conventional armature. (Low voltage may, however, be compatible with the low d-c voltages of transistor circuitry).

(2) Limited use of high internal damping in larger sizes, where armature heating absorbs most of the motor output.

(3) Design problems in a-c machines where more costly laminated stator structures may be required, and magnetizing losses in the relatively large, bigger air-gap limit efficiency, especially in small sizes.

Notwithstanding these problems, the printed circuit construction is ingenious and practical and may lead to new possibilities in servo design and packaging.

For more information on available motor parts and applications of printed circuit techniques to motor design, circle 103 on inquiry card.

BEARING SHIELD DESIGN

New Design Keeps Out Dirt

By making a slight design change Micro bearing design engineers at New Hampshire Ball Bearings, Inc., have developed a really effective shield. The difference is as simple as that of the two drawings below, but the result is to reduce by over 70 percent the size of dirt particles which can get into the bearing. The primary function of a shield, of course, is to keep dirt out of the bearing. A contact seal between two rings is incompatible with low torque and will result in wear. The rings must be able to turn independently, so the trick is to close the gap as nearly as practicable.

The standard answer, adapted from big bearings, has been the design in Fig. 1. The shield, fixed to the outer ring, fitted a recess in the inner. It meant a clearance between the shield and the recessed surface of the inner ring as high as 0.007 inches, while that between the shield and the recess shoulder was somewhat larger. There has to be some clearance because of radial and axial play, but the wide

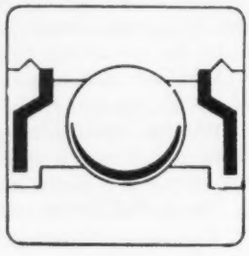


Figure 1

gap in the old design was made necessary by the fact that the recess had to be machined, while the other surfaces are accurately ground.

Now, 0.007 inches may not be a significant gap for big bearings, but it is a barn door for the small ones. The new Micro shield, by fitting the ground OD of the inner ring, can be brought much closer as shown in Fig. 2. The gap in standard Micro shielded bearings as of now is 0.002 inches, or less

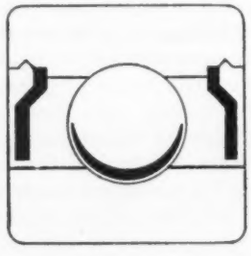


Figure 2

than 1/3 that in the outmoded design.

Other advantages: no corner in which dirt and dust can collect will eliminate the possibility of drag between the shield and the inner ring; full thickness on the side of the inner ring means a broader reference surface for the mounting.

Circle No. 102 on Inquiry Card

Miniature Precision Pots Improved

⅞" diameter, single-turn miniature precision potentiometers have been upgraded electrically, mechanically and environmentally. Weighing only 0.6 oz., in its cup-type, all metal housing, the new Series T comes in servo or bushing mounting styles. Starting torque is .10 oz. in. maximum per section . . . 5 ganged sections are readily available. Helipot, Div. of Beckman Instruments, Inc., Fullerton, Cal.

Circle 246 on Inquiry Card

Elapsed-Time Indicators

Low-cost elapsed-time indicators in bakelite casing are ideal for use in production and utilization studies, maintenance programming, recording running time of machinery, and in electrical and electronic equipment. These unsealed, Marion indicators are available in 3½ inch round and 3½ inch square models. With self-starting synchronous motors for 115 or 230 volt 60 cycle operation, standard 5-digit registers record both total hours and hours in tenths, with easy-to-read white numerals on black backgrounds and tenth markings in red. Marion Electrical Instrument Co., Manchester. N. H.

Circle No. 138 on Inquiry Card

New Coaxial Switch

Coaxial switch for 6⅛ inch coaxial transmission lines has a frequency range of 0 to 450 mc with a VSWR under 1.05. The cw power rating is approximately the same as that of 6⅛ inch coaxial transmission line. Motor-driven and manually-operated models available. Alford Manufacturing Co., Boston, Mass.

Circle No. 198 on Inquiry Card

WORTH FILING

Capacitor Data

Hermetically sealed subminiature paper and plastic film capacitors, designed to conform to the requirements of commercial and military applications, operate at 230C and 125C respectively. Both inserted tab and extended foil section construction is available. In general, inserted tab types are smaller in case size and operate efficiently down to 10 volts D.C. For less than ten volt operation, and where unusual circuit requirements make the losses at resonance critical, extended foil sections should be specified.

Source: Sangamo Electric Co.
Springfield, Ill.

For your copy: Circle No. 215 on Inquiry Card

Mica Button Capacitor Report

High temperature silvered Mica Button Capacitor is especially designed for continuous operation in the wide temperature range of −50 C to +230 C. The unit has high stability and low inductive characteristics, and is available in the capacity value of .004 MFD. in a rating of 200 working volts DC.

Source: Sangamo Electric Co.
Springfield, Ill.

For your copy: Circle No. 222 on Inquiry Card

FREE ENGINEER'S FACT FILE

A Complete Manual on

MERCURY PLUNGER RELAYS

For all loads up to 60 Amps or 5 H.P.

Single Pole

Double Pole

Triple Pole

FREE. Brand new edition, fully illustrated. Rated as the standard reference manual on all types and applications of Mercury Plunger Relays. 1, 2 and 3 pole hermetically sealed, compact and miniature units that provide millions of continuous makes and breaks without maintenance. No pitting or corrosion.

Send for FREE FACT FILE and 30-day Free Test details.

EBERT ELECTRONICS CORP.

212-78 Jamaica Ave., Queens Village 28, N.Y.

Canada: Philips Electronics Industries Ltd.
116 Vanderhoof Ave., Toronto 17, Canada

CIRCLE 29 ON INQUIRY CARD

RUGGED and RELIABLE

New!

TRANSISTORIZED

The A. W. HAYDON COMPANY'S TRANSISTORIZED SUB-MINIATURE ELECTRONIC TIME DELAY RELAYS!

SAVE SPACE AND WEIGHT!

	Miniature Series	Sub-Miniature Series
Cross Section	1 7/16" x 1 21/32"	31/32" x 1 3/16"
Length	2 1/4" long	2" long
Weight	6 ounces	3 ounces
WRITE FOR:	Bulletin AWH TD-503	Bulletin AWH TD-504

TEST-PROVED PERFORMANCE!
High Temperature: 125°C (250°F)
Vibration: 2000 CPS at 15 g.
Contact arrangements up to 4 pole double throw.
Unique transistorized R.C. time constant network.
Time Delays from 50 MS to 120 seconds. Longer Delays available.
Hermetically sealed housings.

MEET REQUIREMENTS OF MIL-E-5272A.

The A.W. HAYDON Company

239 NORTH ELM STREET, WATERBURY 20, CONNECTICUT

Design and Manufacture of Electro-Mechanical Timing Devices

CIRCLE 30 ON INQUIRY CARD

Norbert Wiener

Nonlinear

Because Dr. Norbert Wiener was reluctant to strain his eyes in the preparation of a new manuscript, his colleagues persuaded him to present the material in a series of lectures. While Dr. Wiener lectured, Dr. Yuk-Wing Lee photographed the blackboard as rapidly as Dr. Wiener filled them with formulae; meanwhile a tape recorder picked up Dr. Wiener's discussion. Dr. Lee and Prof. Bose translated the photographs and tape into a manuscript which became "Nonlinear Problems in Random Theory."

Now I am going to discuss the analysis and synthesis of networks that are nonlinear. I am going to bring out that we can discuss the behavior of nonlinear networks, under certain very general conditions, by the response to a Brownian or shot-effect input. One fact about the shot effect is that shot effect can, in a certain sense, imitate any input. That is, suppose, as in Figure 10.1, that we have a finite number of gaps. There is a finite, nonzero probability that a Brownian motion will go through these gaps. If we move these gaps closer together and make them narrow enough, the set of gaps can "approximate" as closely as we desire any continuous motion, and still there is a finite probability that a Brownian motion will pass through them. So, unless a network is so dividing time that this approximation is no longer good, the response of the network to Brownian motions gives us essentially the response to any motion.

For the present, we shall take the network to be a black box with two inputs and two outputs. I do not know why boxes are black, but boxes are *ex officio* black. Now, it is easy to make a shot-effect generator in which the total quantity of electricity that passes in a certain time will be rather close to a Brownian motion. Hence, we can study the output of the black box with a shot-effect generator on the input. Assuming that things do not blow up, and so on—these specifications must be made tighter—let us see how the output for shot-effect input can be represented.

We have seen that if we have $x(t, \alpha)$, then any L^2 function of α can be represented by Expression 10.1:

$$\sum G_n[K_n(\tau_1, \cdots, \tau_n), \alpha] \tag{10.1}$$

If I want an effect that is carried along with the input, we have also seen that we are simply making a shift in all of the τ's. Hence, Expression 10.2 is a general representation for a function of t, determined by the whole history of α, which moves along as t moves along, provided that the function is L^2 in α for each t:

$$\sum G_n[K_n(\tau_1 + t, \cdots, \tau_n + t), \alpha] \tag{10.2}$$

Now, we want to give the characteristic of an electric circuit, i.e the output in terms of the input: that is, of a four-terminal network in general, which includes two-terminal networks as a special case. Notice, I am not assuming conservation of energy. Amplifiers are allowable networks provided the output does not blow up, and provided that the output is an L^2 function of the input. Assumptions that prevent explo-

Although in recent years great interest has developed in the application of random theory to non-linear processes, not much information on the subject has found its way into print. This article on non-linear systems is one of a series of Dr. Wiener's lectures given at M.I.T. for a special group of advanced students; the series fills the need for a comprehensive study of non-linear problems in random theory and marks the opening of a new field. To maintain the flavor of Dr. Wiener's lectures, this article—and the book from which it was taken—is written in an informal style, very largely as he spoke the material in the lectures.

Systems

siveness are important. We can take some networks and represent their characteristics in the form of Expression 10.2. Explosive networks, which include networks that are not explosive in the strict sense but that have intrinsic oscillations of their own, will not go this way. We are assuming some sort of a deadbeat nonlinear network which does not go into spontaneous oscillation, so that it does not depend on the infinite past. If the response of this apparatus depends on the remote past, then the Brownian motion is not a good approximation because we shall always have to consider the remote past.

So we are considering nonlinear networks of a certain deadbeat character, in which the output is asymptotically independent of the remote-past input, and in which it is L^2. Another thing, Expression 10.2 is a little too general for the characteristics of a nonlinear network, since the output of a nonlinear network depends not on the future of the input but only on the past of the input. Nevertheless, it depends on the input; hence by restricting Expression 10.2, we can get the sort of output we can realize. I am going to do this a little later.

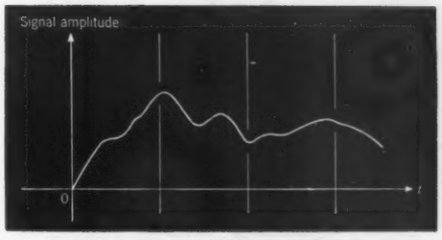


Figure 10.1

I want to contrast what we are doing with what is done in linear networks. In linear networks, the standard input has been a trigonometric input. That comes from the fact that if we put two trigonometric inputs into a linear network, the outputs add. We can study each separately, and they do not mix. In a nonlinear network, they do mix, and we get no great advantage by bringing in trigonometric functions. In other words, trigonometric functions are functions that have a certain type of invariance in time: that is, except for the phase, it makes no difference where we start. Trigonometric functions have a linear invariance with respect to the translation group. The Brownian motion has an invariance that is much more than linear with respect to the translation group. In other words, we are working now with complete independence at different times.

In Expression 10.1, if the kernels, $K_n(\tau_1, \cdots, \tau_n)$, depend only on the past of their arguments, then we have the sort of a characteristic that can actually be realized in a network where the output depends only on the past of the input. What I can do is work with a closed set of functions,

$$\{\phi_n(t)\} \tag{10.3}$$

depending only on the past. Since these are a closed set of functions, I can represent anything depending on the past in terms of the coefficients of these functions. Notice the sort of expressions that I can get. The

This article on non-linear systems was taken from "Non-Linear Problems in Random Theory" by Norbert Wiener, copyrighted by the Massachusetts Institute of Technology and published jointly by the Technology Press and John Wiley & Sons, Inc. Copies of the book ($4.50) may be ordered directly from Technology Press, Room 14N-228, Massachusetts Institute of Technology, Cambridge, Mass. Descriptive literature detailing the book's fifteen chapters may be had by circling no. 93 on the reader inquiry card.

Nonlinear Systems (cont.)

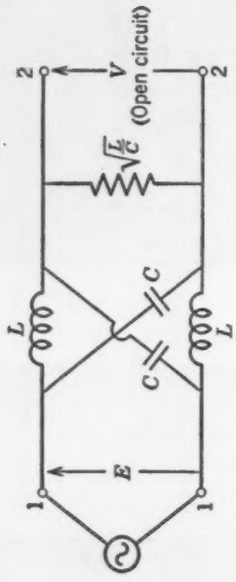


Figure 10.2

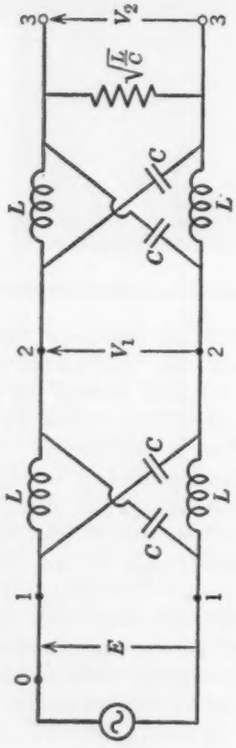


Figure 10.3

constant presents no problem. For the linear term, when I have Expression 10.4, for all n, I know everything that is to be known linearly, if the ϕ_n's are a closed set on the past.

$$\int \phi_n(t)\, dx(t, \alpha), \qquad n = 1, 2, \cdots \tag{10.4}$$

Therefore, $G_1[K_1(\tau), \alpha]$ in Expression 10.1 can be obtained by a linear combination of Expressions 10.4. Suppose that I go to the next order. I am using the generalization that, if a $K_n(\tau_1, \cdots, \tau_n)$ is not symmetrical, I add on all permutations and make it symmetrical. Now, if I know

$$G_2[\phi_m(\tau_1)\, \phi_n(\tau_2), \alpha], \qquad m, n = 1, 2, \cdots \tag{10.5}$$

then I know everything about my quadratic terms, since I can express all the G_2's as a linear combination of terms in Expression 10.5 due to the orthogonality development. That is, if the ϕ_n's are a closed set, then the functions in Expression 10.5 or their symmetrizations are a closed set in two variables. Similarly, if I consider

$$G_3[\phi_{m_1}(\tau_1)\, \phi_{m_2}(\tau_2)\, \phi_{m_3}(\tau_3), \alpha], \qquad m_1, m_2, m_3 = 1, 2, 3, \cdots \tag{10.6}$$

then I have a development for the cubic term. I can get any cubic expression from Expression 10.6.

So the question comes of getting a suitable set of ϕ's for the expansion of the K's. If I can get such a suitable set of ϕ's for the K's, then I have a way of analyzing the output in terms of the input, and, as we shall see later, I have a way of synthesizing that output in terms of that input. So, we shall now discuss—and this goes back to some old work of Professor Y. W. Lee and myself—a particular set of orthogonal functions of the past in terms of which we can do this development. These are the so-called Laguerre functions. I want to discuss the Laguerre functions in two ways, mathematically and from an engineering viewpoint, i.e. how the Laguerre functions of the past of the input can be attained by instruments from the input. I shall then go into the matter of synthesis and analysis of electric networks.

The first thing that I want to do is to bring out some simple properties of the one-stage lattice depicted in Figure 10.2. Note that there is no difficulty working on open circuit, since there are instruments that are actuated by voltage without taking appreciable current, in particular, those employing cathode followers. The question is: What is the output of the simple lattice in terms of the input? We can determine this output in terms of frequency or in terms of time. It is quite clear that the output cannot depend on the future input; it cannot in any electric circuit. Now, if ω is the frequency,

$$\frac{V(\omega)}{E(\omega)} = \frac{1 - i\omega(LC)^{1/2}}{1 + i\omega(LC)^{1/2}} \tag{10.7}$$

The important thing to notice about Equation 10.7 is that the simple lattice is a phase shifter without being an amplitude shifter. Furthermore, the input impedance of the lattice is a pure resistance equal to $(L/C)^{1/2}$.

By the way, the compression of the apparatus that is about to be shown originates with Professor Lee. I think it came about in this way. I saw that electric circuits could realize impedances of this sort, and Professor Lee pointed out that these circuits would dovetail into one another, so that the elements of one circuit could also be used for the next, allowing a much more compact and economical way of making this type of circuit. I think that is a fair account.

Now, consider two stages on open circuit, as in Figure 10.3.

Note that for the first stage nothing has changed, since the second stage appears to the first stage to be identical to the original resistance, $(L/C)^{1/2}$.

Thus,

$$\frac{V_1(\omega)}{E(\omega)} = \frac{1 - i\omega(LC)^{1/2}}{1 + i\omega(LC)^{1/2}} \tag{10.8}$$

$$\frac{V_2(\omega)}{E(\omega)} = \left[\frac{1 - i\omega(LC)^{1/2}}{1 + i\omega(LC)^{1/2}}\right]^2 \tag{10.9}$$

This process can be repeated as often as we want. We continue to replace the resistance by an additional stage, so that we can obtain a transfer characteristic of the form

$$\frac{V_n(\omega)}{E(\omega)} = \left[\frac{1 - i\omega(LC)^{1/2}}{1 + i\omega(LC)^{1/2}}\right]^n \tag{10.10}$$

It is possible to multiply all of the transfer characteristics by an additional factor, $1/[1 + i\omega(LC)^{1/2}]$, by simply placing an inductance of value L between the source and the first stage, i.e. between the terminals 0 and 1 in Figure 10.3. I now have a network that gives me a set of functions:

$$\frac{[1 - i\omega(LC)^{1/2}]^n}{[1 - i\omega(LC)^{1/2}]^{n+1}} \tag{10.11}$$

The important point that I am making is that we can simultaneously get any number of voltage transfer ratios of the form of Expression 10.11. In order to avoid carrying this confounded $(L/C)^{1/2}$ along, we shall just choose our units so that it is 1. This is essentially a choice of time units. Hence we get

$$\frac{(1 - i\omega)^n}{(1 + i\omega)^{n+1}}, \qquad n \geq 0 \tag{10.12}$$

The question comes: What is the operator in time? In order to get that operator, we take the Fourier transform of Expression 10.13. Since the Fourier transform of an operator in frequency gives us an operator in time, we take

$$\int_{-\infty}^{\infty} \frac{(1 - i\omega)^n}{(1 + i\omega)^{n+1}} e^{i\omega t}\, d\omega \tag{10.13}$$

Instead of working this out, I want to give another approach, and then we shall compare them. I am turning things around and working with t positive rather than negative, but this can be turned around again equally easily. Now I say that the functions

$$t^n e^{-t}, \qquad 0 \leq t < \infty, \qquad n = 0, 1, 2, \cdots \tag{10.14}$$

are all functions of L^2, and it is not difficult to prove that they are a closed set of functions of L^2. I may go into that later. Whether they are closed or not, being of L^2, they can be normalized. Consider

$$\int_0^{\infty} (e^{-t})^2\, dt = \tfrac{1}{2} \tag{10.15}$$

So, if I take $(2)^{1/2}e^{-t}$, I have a normalized function. Then I go through the orthogonalization process. I take

$$(at + b)e^{-t} \tag{10.16}$$

and submit it to two conditions: that it should be orthogonal to e^{-t} and that it should be normal. First, I obtain

$$\int_0^{\infty} (at + b)e^{-2t}\, dt = 0, \quad \text{giving} \quad b = -\frac{a}{2} \tag{10.17}$$

Next, I obtain

$$a^2 \int_0^{\infty} (t - \tfrac{1}{2})^2 e^{-2t}\, dt = 1, \quad \text{giving} \quad a = (\tfrac{4}{3})^{1/2} \tag{10.18}$$

Locking screws with LOCTITE increases production 23%

Assembling Hobbs Hour Meters

Mr. LeRoy L. Rasch
John W. Hobbs Div., Stewart-Warner Corp.
Springfield, Illinois, says:

"We all try to cut costs. For example, we used a resin-type product to hold screws in assembling Hobbs Hour Meters. It was necessary for a girl to dip a little piece of wire into the compound, transfer it to the screw hole, and then assemble the screw. With 18 screws this was a slow and tedious job. We switched to LOCTITE Sealant and increased production while making the job easier for the girls. Operators now produce 23% more meters per hour thanks to LOCTITE! This increased production is accomplished by tumbling large batches of screws with LOCTITE in a polyethylene bag. The screws, treated and ready, are spread in front of the operator within easy reach. LOCTITE will not harden in air, but sets firmly when screws are assembled. LOCTITE saves us time and money by virtually eliminating the labor of applying the staking compound to the screws. LOCTITE cut costs for us with no effort at all."

LOCTITE is a thin liquid that hardens when confined between closely fitting metal parts. One drop replaces all size lock nuts, lock washers, lock screws, staking, jam nuts and interference threads. It forms a tough heat and oil resistant bond that resists any amount of vibration . . . yet ordinary tools will remove fasteners. LOCTITE requires no heating or mixing . . . treated parts can be stored for days . . . lock only when assembled. Write for literature and free sample.

LOCTITE® SEALANT
AMERICAN SEALANTS COMPANY
109 Woodbine St., Hartford 6, Conn.
See LOCTITE Booth 1653
Design Engineering Show
CIRCLE 31 ON INQUIRY CARD

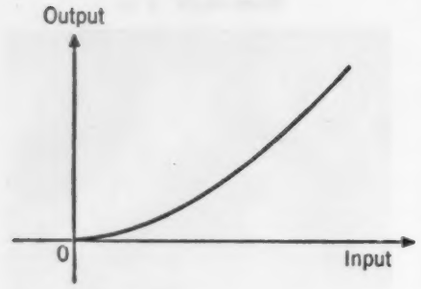


Figure 10.4

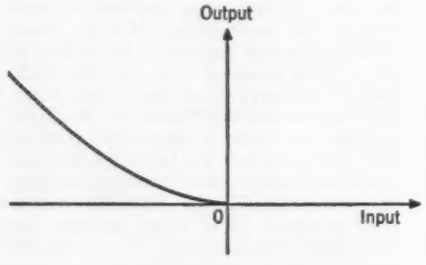


Figure 10.5

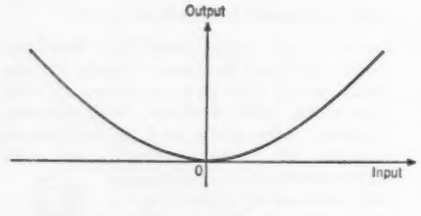


Figure 10.6

Nonlinear Systems (cont.)

Thus, $(\frac{4}{5})^{1/2}(t - \frac{1}{2})e^{-t}$ is normal and orthogonal to the first function. I keep this process up indefinitely. These functions will be closed over 0 to ∞ since they are obtained by a normalization of a closed set of functions. Therefore, any function can be represented in terms of them. They give me a complete representation of the present and past. Now, I say that these normal and orthogonal functions are just the functions given by Expression 10.13 except for a multiplicative constant that is different for each n. This can be shown. In other words, I get from the apparatus consisting of the cascade of simple lattices plus an initial series inductance outputs of the form of Expression 10.4 when the input is shot noise. The ϕ_n's are the Laguerre functions.

I obtain the appropriate G's in the following way. First note that the G's are functions only of the outputs of the Laguerre network and hence are operators depending only on the past. Consider

$$G_{\sum_k n_k}\left\{\prod_k \phi_k{}^{n_k}, \alpha\right\} \tag{10.19}$$

Expression 10.19 gives me a closed basis for the G's of any expression whatever, because I have a closed set of symmetrical K's. Now, I have stated previously, and it is easy to verify, that, since the ϕ's are orthogonal, Expression 10.19 can be rewritten as

$$G_{\sum_k n_k}\left\{\prod_k \phi_k{}^{n_k}, \alpha\right\} = \prod_k G_{n_k}\{\phi_k{}^{n_k}, \alpha\} \tag{10.20}$$

These are the so-called Hermite polynomials in the coefficients of the Laguerre functions of the past. I can obtain all terms in Equation 10.20 if I can do the following things: if I can obtain at each time the Laguerre coefficient of the past, if then I can obtain a polynomial in this which will be a Hermite polynomial, and if then I can multiply these polynomials with one another.

From the standpoint of electrical engineering, what must I do to accomplish this by apparatus? Well, one thing I must be able to do is to add voltages, but there is no problem about that. Since I am also obtaining polynomials, I must be able to multiply voltages. Then if I can add and multiply voltages, there is no problem in getting all these terms. How can I multiply voltages? That is easy. Suppose that I have one particular instrument which is a square-law rectifier. If I have a voltage $V(t)$, I want an apparatus that will give a voltage $V^2(t)$. That is, I want a nonlinear apparatus with that kind of characteristic. There are various ways of getting it, but the general principle involves using a push-pull. Suppose that I get the sort of characteristic shown in Figure 10.4, but its exact shape does not matter too much. Then, I can also get the characteristic of Figure 10.5, which is the same characteristic as Figure 10.4 but reflected about the 0-input line. There is no problem in getting the rectifier to work the other way. So, a vacuum tube or a transister can very easily be made, by push-pull, to give the sort of characteristic shown in Figure 10.6. If I work on a narrow part of this curve, the narrower the better, and then amplify, I shall approach a square characteristic. So, square-law rectifiers are technically not difficult to obtain. In order to multiply $V_1(t)$ and $V_2(t)$, I form $V_1(t) + V_2(t)$ and $V_1(t) - V_2(t)$ electrically. Then with the square-law device, I get $[V_1(t) + V_2(t)]^2$ and $[V_1(t) - V_2(t)]^2$. There is no trouble subtracting voltages, so I subtract and obtain $4V_1(t)\,V_2(t)$. Therefore, I can multiply voltages with existing apparatus. Then having multiplied voltages, I can multiply again. I not only can square but I can cube. I can get fourth powers. I can get polynomials of finite degree. Therefore, I can get Hermite poly-

nomials. So there is no problem in getting Hermite polynomials and products of Hermite polynomials, since I can multiply the different Laguerre coefficients of the past. Since I can add up the different Hermite polynomials, I can synthesize anything that can be synthesized out of my symmetric functions; i.e., I can approximate as closely as I want any function of the past that moves along with a given function. In other words, I can synthesize any nonlinear characteristic that is independent of the remote past and is L^2. Therefore, I have here a universal method for synthesizing.

Now the question is: Can I analyze? Knowing what a function is, how can I determine the coefficients in my development? How can I express the thing in the Hermite polynomials in the coefficients of the Laguerre polynomials, and write down the characteristics of the system? The important point is that, if I can do this for nonlinear circuits, I have done the equivalent of what I do regularly by impedances for linear circuits. That is, if I express how the circuit will respond to any Brownian input, I know how it will respond to any input. Later I shall go into that more.

Now, at least, I want to state what I am doing. I have given a complete characterization of a circuit. I have analyzed it. The important thing to realize is that impedance or voltage ratio is not an adequate way of characterizing nonlinear circuits. Many years ago, nearly forty years, I was working with Professor Vannevar Bush on these problems, and we tried to put the question: How can we define the impedance of a nonlinear circuit? The answer is that we do not want the impedance of a nonlinear circuit. The impedance is not an adequate characterization of the behavior of the circuit; that is, the behavior of a circuit cannot be given by considering merely a trigonometric output. What we want is the behavior of the circuit with a shot-effect input, and then we shall have a theory that is equivalent, parallel but not identical, to impedance theory.

I shall be able to get my coefficients in terms of averages. These averages will be averages involving α. What I can get easily enough in a circuit is a time average. I am going to go into the details of that in the next lecture. The time average is, in general, not the same as the α average, but under the ergodic hypothesis time averages will almost always be α averages. Therefore, if we have ergodicity, this will work. Furthermore, the ergodic hypothesis is satisfied by the Brownian motion. That is, if we translate a Brownian motion in time, then that transformation gives a measure-preserving transformation of α, and it can be shown that this measure-preserving transformation has no invariant sets that have a measure if this measure is other than 0 or 1. In other words, by taking a particular shot-effect input and obtaining time averages, we can obtain α averages that will be what we need for obtaining coefficients. There are several questions here: There is the question of how to relate the α averages to the coefficients, and there is the question of how actually to get α averages. I shall discuss this in the next lecture. We have nearly finished the synthesis problem for nonlinear circuits, and we shall take up the analysis problem in the next lecture.

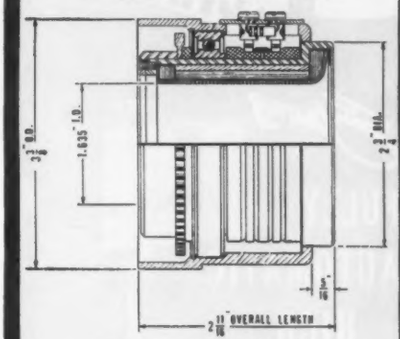
Nonlinear Systems II

We now come to the problem of analyzing a system. Consider two black boxes, one of which has known characteristics, the other being the unknown. One of the things that I can do is to interconnect these boxes in the way shown in Figure 11.1, with their inputs paralleled across a

Deflection
YOKE
specialists

COMPLETE LINE for every Military and Special purpose . . . in PRODUCTION QUANTITIES . . . or CUSTOM DESIGNED to your specific requirement.

FOR PPI DISPLAYS
Compact Rotating Coil Yoke



Stock Type Y25 illustrated

OTHER ROTATING TYPES available with fixed off-centering or rotating off-centering. Many mechanical and electrical variations.

FIXED TYPES with push-pull windings. Low current coils for slower sweep speeds. Low impedance coils for transistor drives.

Neck diameter, core material, configuration, deflection angle and electrical design to your precise spec. For engineering help, contact Dr. Henry Marcy today.

syntronic
INSTRUMENTS, INC.
100 Industrial Road, Addison, Illinois
Phone KIngswood 3-6444

CIRCLE 4 ON INQUIRY CARD

Especially Adaptable to-
PROCESSES INVOLVED in the PRODUCTION of PRINTED CIRCUITS
Strong
FULLY AUTOMATIC HIGH INTENSITY CARBON ARC PRINTING LAMPS

—employ a point source of light at the arc crater, rather than in an uncertain flame, which results in absence of undercutting of image.
The accurately formed reflectors are scientifically designed to gather the light from its source and distribute it so as to obtain utmost light uniformity and maximum coverage.
Stability of light is obtained by means of a variable speed precision carbon feed motor which maintains constant arc gap length.
Producing much more usable light than other sources, exposure time can be cut to a small fraction. Permit much faster production.
Single and three-phase models for use with printing frames of all sizes.
Send for free descriptive literature and prices.
THE STRONG ELECTRIC CORP.
274 City Park Ave., Toledo 1, Ohio
Strong A GENERAL PRECISION COMPANY
A SUBSIDIARY OF GENERAL PRECISION EQUIPMENT CORPORATION
CIRCLE 5 ON INQUIRY CARD

Nonlinear Systems II (cont.)

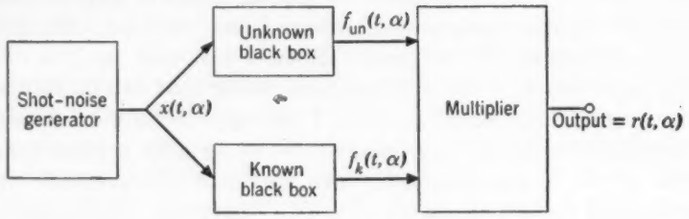


Figure 11.1

shot-effect generator. We then multiply their outputs—we suppose that we have multipliers—to obtain the system output $r(t, \alpha)$.

The unknown black box will have an output

$$f_{un}(t, \alpha) = \sum_n G_n[K_n(t + \tau_1, \cdots, t + \tau_n), \alpha] \tag{11.1}$$

The other box will have an output

$$f_k(t, \alpha) = \sum_n G_n[H_n(t + \tau_1, \cdots, t + \tau_n), \alpha] \tag{11.2}$$

Then, the product output of the system will be

$$r(t, \alpha) = \sum_m \sum_n G_m[K_m(t + \tau_1, \cdots, t + \tau_m), \alpha] \times G_n[H_n(t + \tau_1, \cdots, t + \tau_n), \alpha] \tag{11.3}$$

If I consider the time average of this product, it will be

$$\lim_{T \to \infty} \frac{1}{2T} \int_T^T r(t, \alpha)\, dt, \quad \text{for almost all } \alpha \tag{11.4}$$

But we know that the transformation we get by adding t to all of the Brownian motions is a measure-preserving transformation of the Brownian motions, and this measure-preserving transformation is an ergodic transformation. We have already seen that. Therefore, Expression 11.4 is equal to

$$\int_0^1 d\alpha \sum_m \sum_n G_m[K_m(\tau_1, \cdots, \tau_m), \alpha] G_n[H_n(\tau_1, \cdots, \tau_n), \alpha] \tag{11.5}$$

That is the result of the ergodic theorem. For almost all α, the phase average is the same as the time average.

We now bring up material that we have already covered. When the m's and the n's are different, the integration with respect to α gives 0. When the m's and n's are the same, we get

$$n! \int \cdots \int K_n(\tau_1, \cdots, \tau_n)\, H_n(\tau_1, \cdots, \tau_n)\, d\tau_1 \cdots d\tau_n \tag{11.6}$$

Thus, if we read the average value of $r(t, \alpha)$, we obtain

$$\lim_{T \to \infty} \frac{1}{2T} \int_T^T r(t, \alpha)\, dt = \sum_n n! \int \cdots \int K_n(\tau_1, \cdots, \tau_n)\, H_n(\tau_1, \cdots, \tau_n)\, d\tau_1 \cdots d\tau_n \tag{11.7}$$

Since the known box can be made anything we want, we can, in particular, choose it to be a "one-term" box. We can make that particular H

$$H_n(\tau_1, \cdots, \tau_n) = \prod_{i=1}^{n} \phi_k(\tau_i) \qquad (11.8)$$

where the ϕ_k's are the Laguerre functions. If we have a set of H's of this sort, which correspond to the product of Laguerre functions, the average output will be, except for the $n!$, the K_n times the known Laguerre function. In that way we can get the development of K_n in terms of products of Laguerre functions, and we have the material to resynthesize the unknown box. That means we have an analysis of the system and a synthesis procedure.

There are one or two little tricks that we can do in getting our average. I shall not go into the details here, but it turns out that if we take some random quantity of the sort shown in Figure 11.2 and average it over a long period with the weighting of Figure 11.3, or a weighting that falls off exponentially, as shown in Figure 11.4, the averages will almost always be the same. I can go through the computations, but that can be easily checked. In other words, we may compute the time average in Equation 11.7, using an exponential damping of the past.

We may do the multiplication and averaging of $f_{un}(t, \alpha)$ and $f_k(t, \alpha)$ electrically, as we do all the others, but one of the ways of obtaining the average product with a weighting function is to use an electrodynamometer. Such an electrodynamometer is shown in Figure 11.5. The electrical torque on the dynamometer is proportional to the product of the input voltages V_{un} and V_k.

But now suppose that we mount on the shaft of the electrodynamometer a copper disc, and put an electromagnet across that disc, as shown in Figure 11.6. The electromagnet is supplied from an external source. This will give us an exponentially damped average of the past. The heavier the damping, the farther the averaging extends into the past.

We see what will happen. The damping will prevent the shaft from turning easily. The long-term effect of this is to average, with a weighting function, the previous shaft positions. Then, as we increase the damping by letting the current in the electromagnet approach infinity, the shaft position asymptotically approaches the average of the product of V_{un} and V_k.

Using this instrumentation, we obtain a reading on the electrodynamometer of the average of the product for a given test box, and that gives us the integral in Equation 11.7 with probability 1, which is as good a value as we can get in engineering. If we have a Hermitian polynomial in the Laguerre function box and an unknown box, connect them in this manner, read the stationary position for the product, and divide by $n!$, we obtain the integral of the product of the Hermitian polynomial of degree n and K_n. This gives us the development of K_n in terms of sums of products of nth-order Hermitian polynomials.

In other words, this procedure allows us to use the synthesis apparatus, of which we spoke in the previous lecture, as an analysis apparatus. All we need for the test boxes are Laguerre function boxes, which I have told how to get, since I have told how to make polynomials from them and how to multiply these polynomials. The necessary test boxes are obtained from an assembly of Laguerre function boxes and multipliers. We put in a given unknown box, put in a Brownian input, read the deflection under damping, and thereby obtain the particular coefficients for it. With those coefficients we can assemble the terms and reconstruct the apparatus.

So, what I have given is both an analysis and a synthesis theory of nonlinear apparatus. I gave the synthesis first, but, given the synthesis, I have shown how to get an analysis and remake the apparatus synthetically of these Laguerre and Hermite expressions. END

Figure 11.2

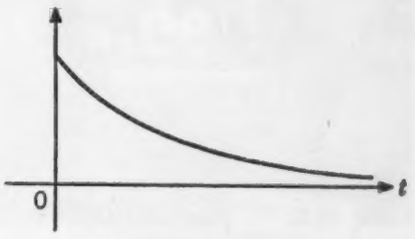


Figure 11.3

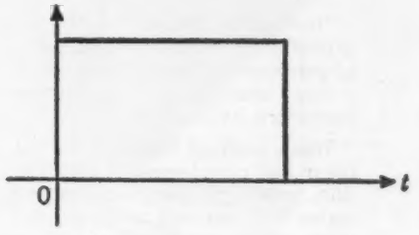


Figure 11.4

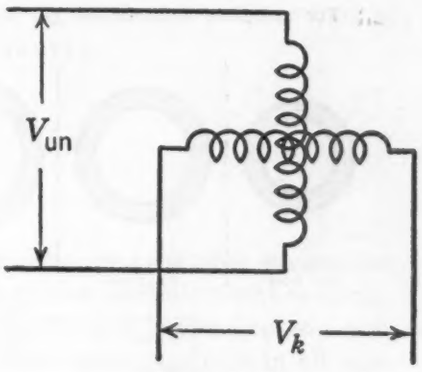


Figure 11.5

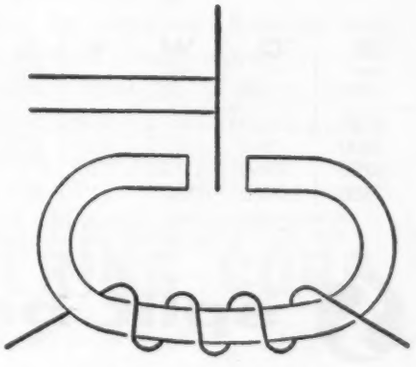


Figure 11.6

new

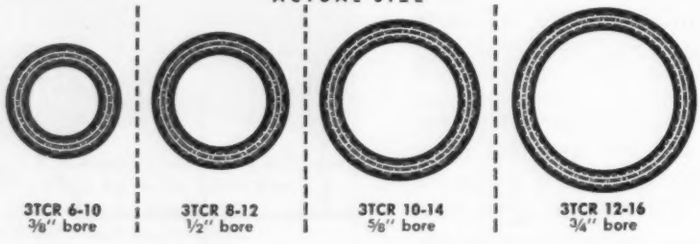
small bearings for big jobs

Thin-section **midget** T series precision ball bearings were designed primarily for instrument application, and to bring new, high standards of performance to their size range. Actual sales experience has shown a much wider range of application for these versatile bearings than heretofore anticipated.

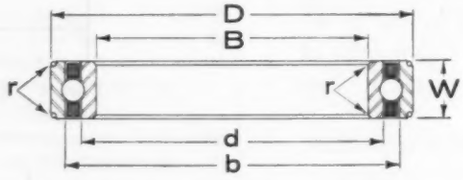
These bearings feature: (1) light, one-piece retainer with true maximum ball complement — good for low torque values. (2) savings from 46% to 90% on space requirements, compared with conventional inch-series ball bearings of equivalent bore size. (3) no loading slot or other design compromise which might limit thrust capacity. (4) high ratio of load capacity to bearing volume. (5) rings and balls of stainless steel; retainer of pressure-molded fibre-reinforced phenolic. Made in precision and ultra-precision grades.

For complete information, get our catalog 59 . . . Write today.

ACTUAL SIZE



3TCR 6-10 — 3/8" bore
3TCR 8-12 — 1/2" bore
3TCR 10-14 — 5/8" bore
3TCR 12-16 — 3/4" bore



*B bore ± .0002	*D o.d. + .0000 − .0004	W width + .0000 − .0050	†r radius	b outer land ± .001	d inner land ± .001	Balls no.	Balls size	‡L lbs.	§S lbs.
.3750	.6250	.15625	.010	.542	.457	16	1/16	77	110
.5000	.7500	.15625	.010	.672	.587	21	1/16	89	144
.6250	.8750	.15625	.010	.797	.712	24	1/16	94	165
.7500	1.0000	.15625	.010	.922	.8375	30	1/16	101	206

Dimensions are in inches. *Tolerances shown are for Precision Grade. Write for Ultra Precision Grade tolerances. †r is maximum fillet radius on shaft or housing that bearing will clear. ‡Radial load capacity at 500 rpm and 2500 hours average life. §Static non-Brinell load capacity.

split ballbearing
A DIVISION OF MPB, INC.
512 HIGHWAY FOUR, LEBANON, NEW HAMPSHIRE
CIRCLE 32 ON INQUIRY CARD

SYSTEMS DESIGN

New System for Aircraft Testing

Electro-hydraulic system for dynamic test of structural and aerodynamic components of aircraft and guided missiles permits simulation of conditions of supersonic flight. The unit, designed around a high performance electro-hydraulic servo system, not only provides for accurate load programming over a wide range of operating conditions, but also enables virtually unlimited test periods. Control signals can activate hold, continue, reset and re-cycle operations. The system is also adaptable to "fail-safe" action. Provision is made to incorporate a four-way solenoid operated spring-return hydraulic valve in the system hydraulic power supply. When the system is operating normally, the fail-safe valve is energized; however, a series of interlocking switches and detector devices combine to de-energize the valve when trouble occurs. Hydraulic pressure to the servo valves in the system is eliminated, resulting in return of the servo actuator to a point of equilibrium. Sanders Associates, Inc., Nashua, N. H.

Circle No. 197 on Inquiry Card

WORTH FILING

Magnetic Amplifier Design Manual

16 page Magnetic Amplifier Design Manual, Engineering Bulletin #403-A, has 45 schematic diagrams and graphs describing magnetic amplifier design and application techniques. Some of the topics covered in the new manual are: signal mixing, voltage and current comparators, automatic pilot systems, electrohydraulic valve drives, gyro and position pickoffs, insulation and cable barriers checker, integrators, limiters, sweep generator potentiometric amplifier circuit, relay tester, LaPlace transform generation, velocity servos.

Source: Acromag, Inc.
Detroit, Mich.

For your copy: Circle No. 164 on Inquiry Card

Servo Components Handbook

An important tool for engineers working on servo systems is Ketay's new "Nomenclature For Rotating Servo Components", a twelve page booklet covering standard MIL type synchros, resolvers, servo motors and tachometer generators. This booklet includes complete explanations of the symbols which identify units and definitions of all important characteristics of units.

Source: Ketay Dept.-Norden Division
United Aircraft Corp.
Commack, L.I., New York

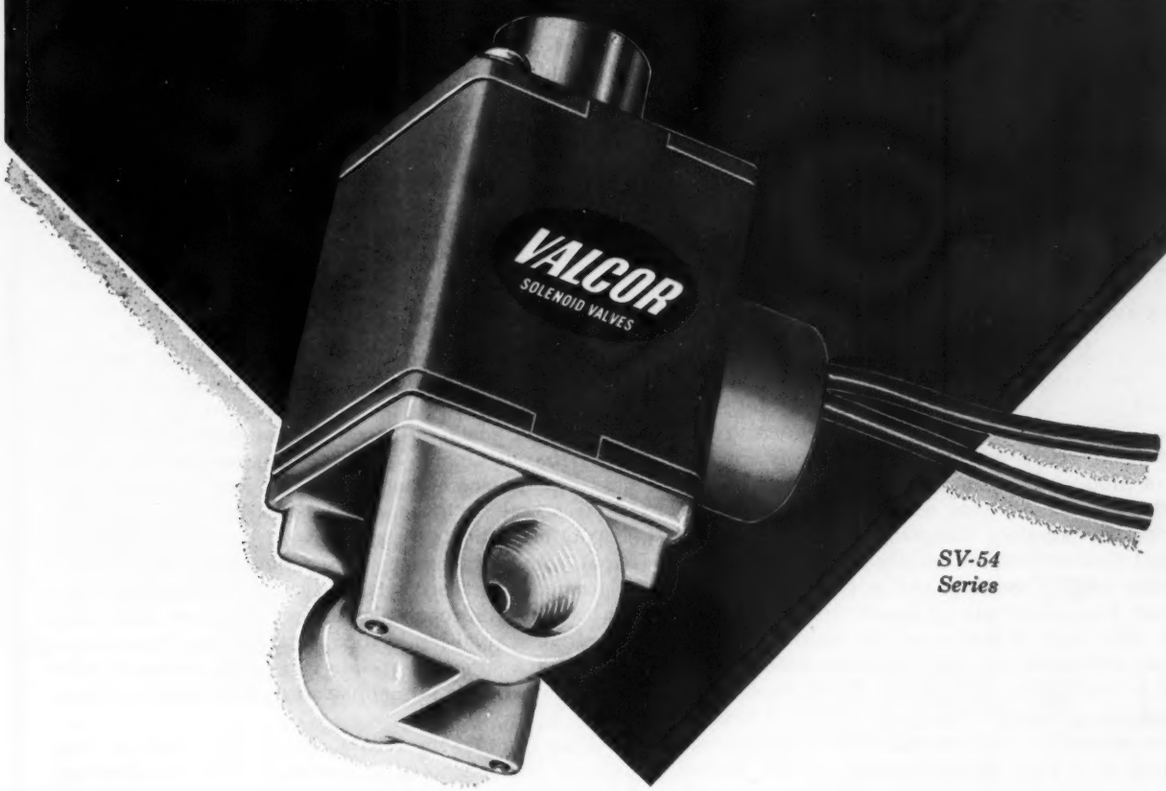
For your copy: Circle No. 217 on Inquiry Card

New 3-Way Nylon-Body Solenoid Valve...

List Priced as Low as $10.75...

(Quantity Discounts Available)

Outlasts, Outperforms Steel!



SV-54 Series

VALCOR'S new 3-way Nylon solenoid valve, SV-54 Series, outlasts and outperforms steel, yet is list priced as low as $10.75! In general purpose and O.E.M. installations, where millions of operating cycles are essential, this new Valcor valve not only works best but costs less.

Its nylon seat outlasts steel...its port threads outlast steel . . . pound for pound it's *3 times stronger than steel.* Dry seal threads, no compound is needed—and they won't loosen even under severe vibration. Nylon is non-corrosive so you have no atmospheric problems. And the stainless plunger is a reliable workhorse for millions of cycles. Bubble tight sealing. Available in normally open, normally closed and "directional control" configurations in all normal AC and DC voltages...1½" square x 3" long (valve illustrated).

Write today for complete technical data on this shock-resistant, pressure-proof valve—the 3-way nylon-body valve, SV-54 Series, that's 3 times stronger than steel, yet costs less. Try it on your toughest application.

VALCOR SOLENOID VALVES

VALCOR ENGINEERING CORP.

5374 Carnegie Avenue, Kenilworth, New Jersey

CIRCLE 33 ON INQUIRY CARD

MATERIALS

STAFF COLUMNIST

RADIATION AND MATERIALS:

Part II

Effects of High-Level Radiation

David Bandel
Associate Technical Director,
TRACERLAB, INC.

The general modes of interaction betwen low level radiation and matter were discussed in a previous column. For instrumental and tracer applications low levels of radiation dosage do not produce any noticeable changes in the properties of most materials. High levels of radiation, however, are capable of inducing profound changes in the mechanical and electrical properties of some materials, particularly organic materials, and these changes must be taken into consideration when materials are to be used in an environment that will subject them to an appreciable flux of ionizing radiation.

NEUTRON IRRADIATION

Neutron irradiation is a more complex case since neutron interactions are highly specific for various elements and more specifically for certain isotopes of elements. Induced radioactivity is a frequent result of neutron interaction with matter. Neutrons are also capable of producing ionization by secondary reactions and in this respect neutrons resemble the more common types of radiation. Generally, neutrons are, at the present time, a problem mainly in equipment concerned with nuclear reactors, and in positions exposed to neutron flux. Materials problems are particularly severe in this field. A review of the radiation effects of neutrons on engineering and electronic materials can be found in Nucleonics, Vol. 14, pp. 54-88, Sept. 1956. The beneficial as well as damaging aspects of neutron irradiation on metals, plastics and semi-conductors are summarized in a very concise manner in this special report.

The more usual problems involving radiation environment, aside from reactors, arises in applications where high levels of beta and gamma radiation or particle accelerators are concerned. High level gamma irradiators are being designed and constructed for food sterilization and several irradiation facilities in existence now are capable of delivering respectable dosages of radiation for materials studies, research in chemical processing and special investigations. Another instance where high level radiation dosage may be an important consideration is in "hot cells" where highly radioactive material is handled or in chemical processing plants where spent nuclear fuels are processed for recovery. In some systems involving relatively low radiation levels where long exposure is a factor, sensitive components should be checked for possible radiation damage—since radiation damage is a function of the total dosage: the product of radiation level, absorption coefficient and time of exposure.

It is not possible to present a detailed picture of high level radiation effects on materials in the space allotted to this column. The special report in Nucleonics cited above fills in some of the details and a recent paper on radiation effects on plastics, "Chemical and Physical Changes in Gamma-Irradiated Plastics," by R. Harrington and R. Giberson which appeared in Modern Plastics, p. 199, Nov. 1958, has a large volume of detail on a wide variety of plastic materials. What we can best consider here is a general view of the action of high level radiation on materials that might be useful in the broader aspects of design problems. More detailed information and actual numbers can be found readily in the references cited above or in the voluminous literature on this aspect of equipment design and performance.

INORGANIC MATERIALS

Inorganic materials generally do not suffer any extensive mechanical damage from radiation other than neutrons. The electrical properties can be markedly affected in some instances; the most important case from the standpoint of electronic components is the loss of semi-conducting properties that junction type devices undergo even at relatively low dosages. The impact of particulate radiation and secondary electrons from gamma radiation causes numerous atomic displacements in the crystal lattice and consequent disturbance of the controlled defect structure built into the original semi-conductor crystal lattice. Devices employing transistors are prone to gradual failure if adequate shielding is not employed to hold radiation dose to fairly low levels.

Glasses and some inorganic crystals become discolored when exposed to radiation. The discoloration of glasses is used to measure radiation dosage with special glasses developed for this purpose. The discoloration is a function of the total dose absorbed. Once the glass has been calibrated under given conditions, it can be used for dosimetry. The discoloration of glasses and crystals disappears upon heating. While no significant changes in mechanical properties accompanies the color change, it is likely that the dielectric properties are affected during irradiation.

ORGANIC MATERIALS

Organic materials undergo profound changes when exposed to high level irradiation. Since the mechanical properties of plastics and polymers are sensitive to chain length and presence of cross-linkages, they are particularly affected by irradiation. The mode of interaction of radiation on organic materials depends upon one of the basic properties of radiation frequently referred to in previous columns, the ability to produce ions and free radicals. Free radicals can cause considerable havoc when turned loose indiscriminately in organic systems.

In some cases, free radicals promote chain scission

so that the plastic material will become soft and gummy. Butyl rubber is a typical example of this type of action. Chain scission also causes certain plastic materials to become brittle and powdery. Teflon is an example of this type of behavior and this material should not be used where appreciable radiation dosage is likely to be part of the environment. Other fluorocarbon polymers are less sensitive to radiation damage than Teflon, but none can be considered outstanding in resistance to radiation damage. In some instances free radicals induce cross-linking of polymer chains, a process analogous to vulcanization. In fact, rubber can be vulcanized by irradiation, and we can look forward to the day when we sit out the Sunday traffic jam on radiation vulcanized tires. Cross-linking makes polymers more resistant to solvents and heat distortion. In this respect controlled irradiation can be beneficial. Irrathene, a cross-linked polyethylene with improved heat resistance, is produced by such controlled irradiation, using high voltage electron accelerators to obtain higher flux densities than radioactive sources can supply conveniently. In many instances both scission and cross-linking processes occur simultaneously, but one of the two processes is generally predominant. Some rubbers will first become gummy and tacky as scission occurs, then later become brittle and cracked as cross-linking begins to predominate.

All organic based plastics eventually suffer a decrease in tensile strength and elongation upon prolonged irradiation. The rate at which this occurs is dependent upon the chemical structure of the polymer, the presence or absence of air and the total or integrated dose accumulated. Plastic materials based upon "aromatic structures" possess the highest degree of resistance to radiation damage. Polystyrene and Mylar are prime examples of this class of materials.

Radiation damage will manifest itself in several ways. Dimensional changes frequently occur before other, more extensive changes can be detected. Some plastics will swell, decrease in density and show the effects of gas bubbling, while others begin to shrink and show fine surface cracks. There does not appear to be any large permanent change in the gross electrical characteristics of irradiated plastics. However, most of the measurements reported have been on materials that have been irradiated but tested in the normal radiation-free environment. One would actually expect that the dielectric properties would show drastic changes while in the radiation field. A large decrease in the volume resistivity of plastics under irradiation has been reported in some studies. Polystyrene shows an anomolous behavior in this respect. At first the resistivity decreases but reverts to a level close to the original value with time. Dissipation factor and dielectric losses would probably be affected adversely in the radiation field. These possibilities must be considered in designing components for use in radiation environments, if leakage resistance and dielectric losses are important parameters.

The effect of radiation on another common electromechanical "component" lubricant should not be overlooked. Organic lubricants are degraded by irradiation in much the same way that plastics are degraded. The degradation appears as a change in viscosity and gradual loss in lubricity. Greases may liquefy and run out of bearings. A considerable effort has been applied to the development of radiation resistant lubricants and several improved lubricating compounds are now available commercially.

LUCITE
PLEXIGLAS
ACRYLIC
ACETATE
BUTYRATE
CAST PHENOLIC
EPOXY RESIN
ETHYL CELLULOSE
KEL-F
LAMINATED BAKELITE
NYLON
POLYETHYLENE
STYRENE COPOLYMERS
TEFLON

BALLS
BOBBINS
BUSHINGS
COLLARS
DETENTS
FINIALS
GROMMETS
HANDLES
KNOBS
MECHANICAL CHECKS
NAME PLATES
PINS
PLATES
PLUGS
RINGS
SPACERS
SPOOLS
STANDS
STRIPS

SIZES: ⅛" to 2¼" LENGTHS: 1/16" to 9"

New e-x-p-a-n-d-e-d production facilities now give you ACE PRECISION on all types of screw machine centerless ground parts and special shapes... all colors... all materials.

Write, wire, phone for samples, prices and Bulletin F listing stock items. Send specifications or blueprints for prompt quotations on specials.

ACE PLASTIC COMPANY
91-44 VAN WYCK EXPRESSWAY
JAMAICA 35, N. Y. • JAMAICA 3-5500

CIRCLE 34 ON INQUIRY CARD

ELECTRONIC ENGINEERS

Clairvoyant Countermeasures*

—ONE OF THE MANY EXCITING PROJECTS ATTRACTING ENGINEERS TO GENERAL ELECTRIC'S LIGHT MILITARY ELECTRONICS DEPARTMENT

Engineers at LMED are developing an "Intelligent" ECM System which will instantly analyze radiations from enemy systems, make decisions and immediately respond with counter-radiations to provide continuous protection for our aircraft.

LIGHT MILITARY DESIGNS ACROSS THE ENTIRE EM SPECTRUM—FROM AUDIO TO INFRARED

The "Clairvoyant" Countermeasures system is typical of LMED's many programs that extend across the entire EM Spectrum. Other diversified programs now under way that offer accelerated career growth and substantial job security include Polaris Fire Control Computers, automated AEW, and a revolutionary Bomb/Nav system.

FOR PROMPT CONSIDERATION send a post card containing the following information: your name, home address, home phone, degree(s) and year(s) received plus the technical areas you are particularly interested in to:

Mr. R. C. Kimm, Div. 29-MD

LMED

LIGHT MILITARY ELECTRONICS DEPARTMENT

GENERAL ELECTRIC

FRENCH ROAD, UTICA, NEW YORK

* Attempting to prove the existence of clairvoyance and telepathy, early experimenters used unique "playing cards" developed by Dr. Karl Zener. LMED's ECM will appear clairvoyant to enemy radars by seeming to know beforehand, the precise signal structure to jam.

CIRCLE 35 ON INQUIRY CARD

MATERIALS

Epoxy Fiber Glass Tubing For Electrical Uses

A new line of epoxy resin-bonded fiber glass tubing possesses exceptionally high tensile and bursting strength as well as optimum electrical properties.

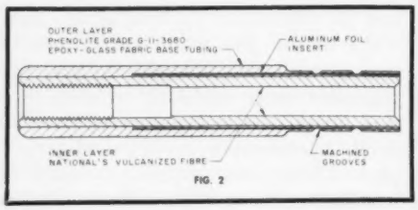


FIG. 2

Typical example of the new Phenolite grade tubing used in combination with other materials is the lightning arrestor for use on power transformers. This part has an outer layer of the epoxy fiber glass material wound around an inside layer of vulcanized fibre. Wound in the Phenolite covering, over part of the tube's length, is an aluminum foil ground shield; the foil is exposed at two points by grooves machined in the Phenolite layer.

Designated as Phenolite Grade G-11-3680 or G-11-3681, depending upon its diameter and wall thickness, the tubing is considered ideal as a material for selected electrical or electronic components. It can be used either by itself or in combination with inner and outer layers of other materials such as vulcanized fibre and metal foil. Either alone or in combinations, the new epoxy fiber glass tubing has such typical uses as: miniature coil forms, lightning arrestors for power transformers, and aircraft fuel gauge probes. The new Phenolite grade consists of a rolled tube of glass fabric bonded with a high heat-resistant epoxy resin. The tubing is available in a very broad range of diameters from ⅜ in. I.D. to 11 in. I.D. with wall thickness from 0.010 in. to 5½ in. Maximum ratio of wall thickness to inside diameter is 1 to 2. The very low water absorption and minimum dimensional change of Phenolite Grade G-11 tubing make it ideal for aircraft fuel gauge probes, coil forms, or parts subjected to weathering in outdoor applications. Its dielectric strength, arc resistance, and low power loss over an extremely wide frequency range should particularly interest switchgear and other electrical apparatus manufacturers, as well as electronic component designers. National Vulcanized Fibre Co., Wilmington, Del.

Circle 225 on Inquiry Card

Low Temperature Insulation

An important technical development by National Research Corporation in the cryogenic insulation field provides a more effective heat shield than heretofore available for storage of liquefied gases at very low temperatures. "The development is of particular interest to the military services because of the rapidly increasing use of liquid oxygen and other cryogenic materials in the propulsion of ballistic missiles and space vehicles," according to J. H. Moore, Vice President. NRC intends to license its technique and know-how in low temperature insulation to industry on a non-exclusive basis.

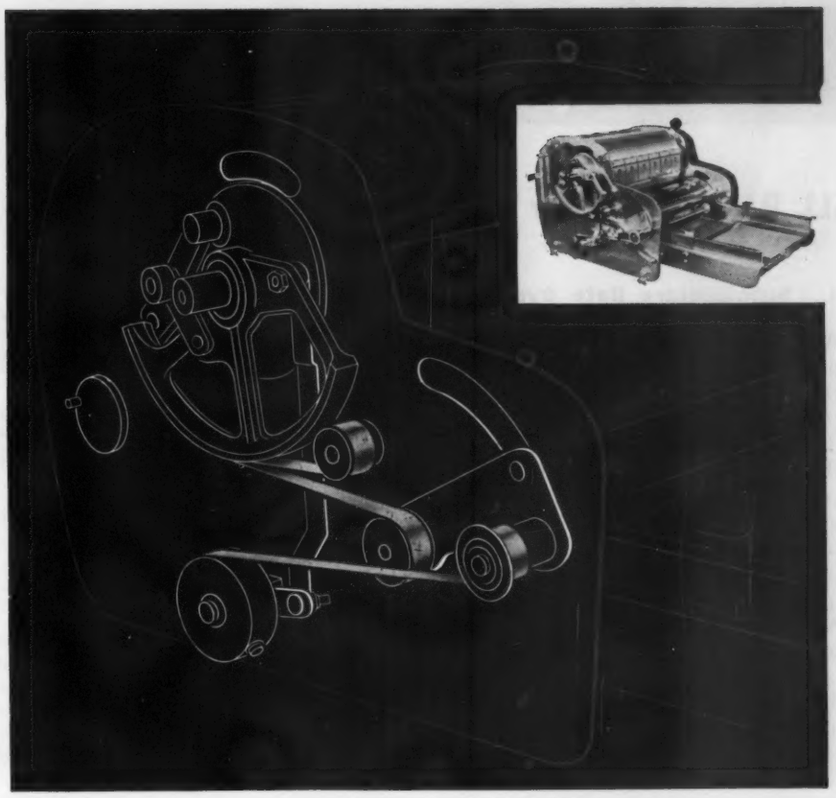
"According to recent tests the NRC insulation is about 15 times better than the commonly used powdered insulations and twice as good on a performance-to-density basis as the very best materials now known to be available commercially," Moore said. He did not reveal technical details other than to say its high performance is due to the use of a combination of radiation barrier and high vacuum.

LOW COST, LIGHT WEIGHT

Cost of the NRC thermal barrier technique should be no higher than that of some lower performance materials now in use, the company indicated. Light weight of the material offers a significant advantage for both transportable and permanent facilities; density is two pounds per cubic foot or less. Substantial savings may be realized in reduction of the bulk of transportation facilities such as railroad tank cars or trucks. More liquid gas may be transported in a given size double-wall vessel since the inner container may be increased in capacity without reducing insulation capability.

Use of the NRC-type heat barrier results in greatly reduced loss of liquid gas from vaporization or "boil off"; a liquid-helium storage container was found to have a heat flux less than 0.0006 BTU-inch per square foot per degree Fahrenheit per hour at a pressure in the insulation space of 10^{-4} millimeters of mercury. This compares with 0.01 BTU-inch for standard powder insulation used in most dewar tanks. New advances in high vacuum techniques, according to the company, make the use of very low pressures—and consequent low thermal losses due to conduction and convection—practical for commercial and field applications. National Research has been a leader in the high vacuum field for 20 years.

Circle 226 on Inquiry Card



Transmit Motion Without Backlash

USING A NEG'ATOR® SPRING

Quiet, gearless transfer of motion without slippage or backlash—still another function of Hunter's versatile design component, the NEG'ATOR constant-tension Spring.

Searching for a gearless method to link and synchronize the action of paper handling rollers to the timing drive assembly on the new "ROCKET" duplicating machine, design engineers at Standard Duplicating Machines Corp. tried cords, cables, chains—found that NEG'ATOR Springs outperformed all.

So, as illustrated, they attached the free ends of two NEG'ATORS to the cam-and-lever driven timing segment and the free end of a third NEG'ATOR to an idler pulley. The constant tendency of the NEG'ATORS to return to their original coiled condition when extended keeps them taut—eliminates backlash. They rewind smoothly on the drive pulleys as the pulleys are returned, under spring tension, to the cycle starting position.

By replacing gear trains with NEG'ATORS, Standard's engineers obtained efficient operation, longer life, quieter operation, and reduced unit cost. The "ROCKET" is said to be the "quietest machine on the market."

Used in the manner described or to counterbalance without mass, maintain constant pressure, deliver retracting force, power portable units, expand a scale, or perform other functions, the constant-tension NEG'ATOR Spring might offer just what you're looking for.

You can learn more about the NEG'ATOR, its characteristics, forms, functions, and applications by reading Bulletin 310N. Send for a copy.

HUNTER SPRING COMPANY

28 Spring Avenue, Lansdale, Pennsylvania

SPRINGS • STAMPINGS • TEST APPARATUS

CIRCLE 36 ON INQUIRY CARD

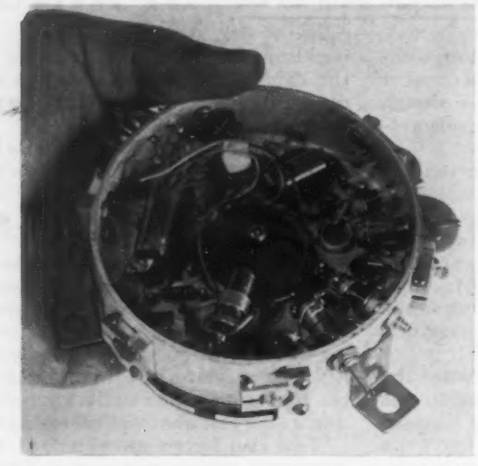
SMALL PACKAGES for SYSTEMS DESIGN

I. Subminiature Rate Gyro Package

A new subminiature rate gyroscope package designed for missile and aircraft flight stabilization provides a complete three-axis angular velocity sensor in a compact, lightweight package for roll, pitch and yaw indication. Measuring only 3.0″ x 3.0″ x 3.0″ overall, and weighing less than a pound, the multi-axis package requires fewer components, is simpler to install and costs less than three separately packaged gyros. In includes three subminiature rate gyroscopes, a phase-splitting capacitor and a current-controlling choke which gives constant pick-off excitation regardless of frequency or temperature variations. Designed by Sanders Associates, Inc., it can be provided with three-channel demodulation where dc output is required. A single, standard cable connection simplifies electrical installation. Three-axis gyro packages of smaller size and lighter weight are available on special order.

Circle No. 110 on Inquiry Card

All components are mounted on a common plate, with the gyro axes mutually perpendicular. The common mount eliminates problems of independent gyro orientation and alignment which occur with separately packaged gyros in multi-axis applications. Components and mounting are designed to minimize shock, vibration and temperature effects.



Beacon transmitter used in Atlas "talking satellite", Project SCORE illustrates one of the packaging formats that can be used. The transmitter is 1⅜″ x 3¼″ diameter and weighs approximately 12 ounces. Output impedance is 50 ohms. Total power consumption from a 20 volts supply is 250 mw. The unit is completely transistorized and illustrates one packaging format available.

II. Beacon Transmitter For Satellite and Space Vehicles

A miniature, low-power combination sub-carrier oscillator transmitter, designed for use in satellite or space-vehicle tracking systems, is now available in production quantities, designed by Applied Science Corporation of Princeton. The transmitter is identical to the beacon transmitter built by ASCOP which broadcasts tracking and temperature signals to ground tracking stations from the successful Atlas "talking satellite", (Project Score).

Carrier frequency of the transmitter can be chosen from any crystal-controlled frequency in the range of 100 to 150 mc. The output power of 30 to 100 mw achieves line of sight operation from 150 to 1000 miles in normal satellite applications. Extremely low power consumption permits the use of the transmitter in vehicle tracking and narrow-band telemetering applications without seriously depleting power supplies even when the transmitter is operating continuously. Tracking signals and restricted bandwidth data can be transmitted simultaneously. The transmitter is intended to be amplitude modulated although phase modulation at subcarrier frequencies up to 22 kc can be used. A self-contained, resistance or voltage-controlled subcarrier oscillator for data transmission is part of the transmitter package.

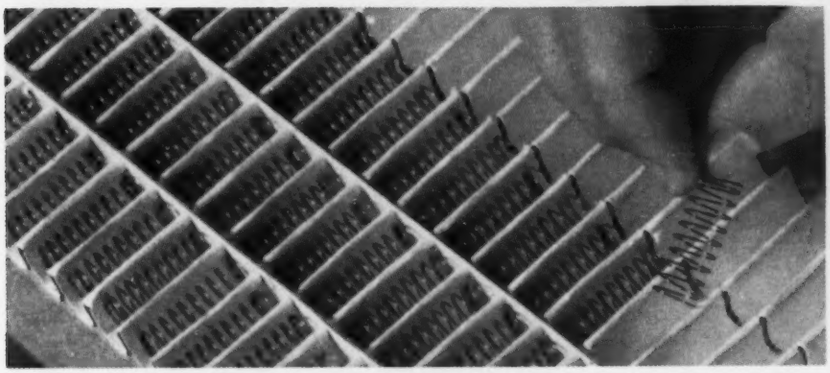
Circle No. 111 on Inquiry Card

III. "Microminiature" Technique Fits One Million Parts In One Cubic-Foot

Revolutionary new fabrication techniques are apparently on the horizon whereby the functions of many ordinary electronics components will be performed by a single tiny unit. The new techniques go by various names: Varo Manufacturing in Garland, Texas talks about microcircuitry. Servo-Mechanisms of El Segundo, California refers to micro-miniaturization. Some engineers talk about "glob" circuits.

- At the recent IRE meeting, W. D. Fuller of Varo discussed how thin films of magnetic and other electrical materials may be deposited so as to form a glob that can carry out many of the functions of conventional electronic circuits, such as amplifying and oscillating.
- David W. Moore of Servomechanisms reported on use of thin film to form tiny electronic circuits, especially circuits for electronic computers. *Continued page* 42

NOW...eliminate tangling...



SAVE assembly time . . .

cut costs, speed operations with . . . Spring Flow®

Spring Flow brings springs, wire forms, and other fabricated-metal parts into your plant packaged for efficient production. No need to waste time untangling—no distortion. Shape and finish are protected in use or storage. Inspection and selection is easier, faster. Special packaging or dispensing speeds up hand or automatic assembly.

Spring Flow cost is frequently offset by resulting savings. Here's how to find out. Show us your spring or metal part and how it is used in your plant. Let us submit a Spring Flow recommendation. Or write for booklet giving more details about Spring Flow.

5909

Associated Spring Corporation

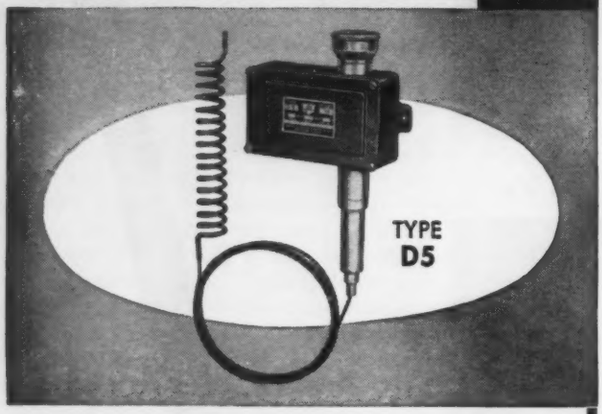
General Offices: Bristol, Connecticut

Wallace Barnes Division, Bristol, Conn. and Syracuse, N. Y.
B-G-R Division, Plymouth and Ann Arbor, Mich.
Gibson Division, Chicago 14, Ill.
Milwaukee Division, Milwaukee, Wis.
Raymond Manufacturing Division, Corry, Penna.
Ohio Division, Dayton, Ohio
F. N. Manross and Sons Division, Bristol, Conn.
San Francisco Sales Office, Saratoga, Calif.
Seaboard Pacific Division, Gardena, Calif.
Cleveland Sales Office, Cleveland, Ohio
Dunbar Brothers Division, Bristol, Conn.
Wallace Barnes Steel Division, Bristol, Conn.

Canadian Subsidiary: Wallace Barnes Co., Ltd., Hamilton, Ont. and Montreal, Que. Puerto Rican Subsidiary: Associated Spring of Puerto Rico, Inc., Carolina, P.R.

CIRCLE 37 ON INQUIRY CARD

MICROMETER-ADJUSTED
REMOTE BULB
TEMPERATURE CONTROL D5



UNITED ELECTRIC's Type D5 Remote Bulb Temperature Control is a precision unit containing a micrometer adjustment for obtaining wide ranges and accurate temperature settings. This control has found extensive use in applications such as laboratory and industrial ovens, water baths, hot plates, etc.

Temperature Ranges	−150°F. to +200°F., 70°F. to 370°F., 100°F. to 650°F.
Switch Ratings	15 amps at 115 or 230 volts AC. Also 20 amps or DC switches on specification.
Switch Types	N.O., N.C., or Double Throw — no neutral position.
On-Off Differential	Approximately 1.0°F. or 2.0°F. dependent on model.
Adjustment	Three-turn, calibrated knob rotated against graduated barrel. Readings and divisions equally spaced over entire range. Adjustment knob includes calibration screw.
Electrical Connections	Made to internally located terminal block via clearance hole in the enclosure.
Capillary Tube Length	Standard length six feet. Other lengths available.
Enclosure	Die-cast aluminum case with black wrinkle finish. Other finishes available.
Mounting	Control head surface mounted in any position by means of dog ears. May also be flush mounted.

UNITED ELECTRIC ***manufactures a complete line of temperature, pressure, and vacuum controls. Additional data on the Type D5 and other standard remote bulb temperature controls are contained in*** **Section 200** ***of our*** **new** ***catalog. Write for your copy now.***

UE®
United Electric Controls
COMPANY
83 SCHOOL STREET, WATERTOWN MASS

CIRCLE 38 ON INQUIRY CARD

NEW TECHNIQUES

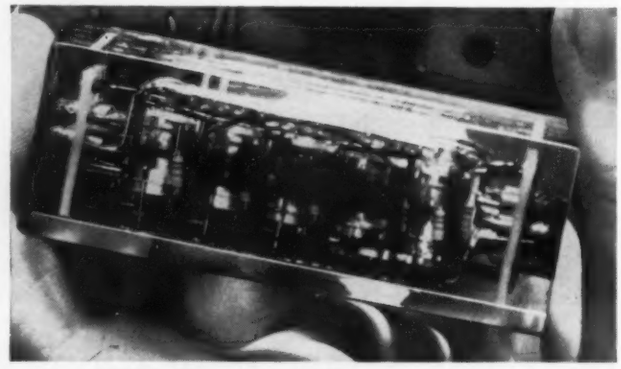
• Radio Corp. of America recently demonstrated a glob-circuit radio set the size of a fountain pen.

Basically, these various techniques involve depositing one thin layer of material upon another until a glob composed of several materials is built up that will function as part of your radio, tv or hi-fi set. In this kind of process, conventional components—the capacitors, resistors and inductors—disappear. They are replaced by these globs. The thin films are formed by vacuum deposition. For example, nickel-iron films are deposited to make up memories for electronic computers. As in the case of most new developments in the electronics industry, the first products more than likely will go into missiles, rockets and radar sets, but in years to come, these globs will probably show up in cheap, compact home entertainment products of almost infinite trouble-free life.

IV. Electronic "Sardine Sandwich"

A new miniaturized technique squeezes up to five times more components into the same space in electronic equipment. Created by engineers of Raytheon Manufacturing Company's Industrial Tube Division in Newton, Mass., the new technique interleaves transistors, resistors and capacitors like sardines and immerses them in a plastic compound that hardens, making them unusually resistant to shock.

More than 100 components can be packed into each cubic inch by eliminating conventional leads and wiring



and welding the components directly to each other. The Raytheon welded module assembly offers a new concept for making high density building-block component assemblies. It has important commercial applications in computers, data processing machines, and all transistorized electronic equipment. Military applications include guided missiles and many airborne, mobile, and portable electronic systems.

The new welded modules are constructed with four elements: the "stick" which is the component welded assembly, the "logic wiring," the terminations, and the potting. In building the "stick" a number of subassemblies are brought together with precision jigs and joined by using a Raytheon Weldpower stored-energy welder. Fitted with precision programming timers the welders fuse the components together with an extremely short and accurately timed burst of energy, safeguarding nearby components from heat damage common when parts are soldered close to each other.

Layers of fine insulated wires form the interconnecting "logic wiring". Molded terminal blocks contain newly designed high reliability connectors allowing proper input

and output connections. When the "sticks" have been assembled and all connections made by welding, the unit is fully tested, then potted.

It is expected that the new welded assemblies will significantly reduce maintenance costs for computers and other complex systems. In addition to the ruggedness and welded-in reliability the modular units can be replaced quickly and substituted directly should a failure occur.

Circle No. 105 on Inquiry Card

3-Pole Commutator Switch Gives 450 Contacts on 3-Inch Diameter

A new design, superior to any produced hitherto, has resulted in a commutator switch which can provide two rows of 180 contacts and one row of 90 contacts in a minimum space. The precision switch, incorporating rectangular contacts precision molded in Supramica 555 ceramoplastic, very easily exceeds the parameters of reliability and noise level achieved by segmented contact rings of printed circuit plates.

The design, produced by Mycalex Electronics Corporation as one of a series of continually improving commutator plates, tested satisfactorily without maintenance or adjustment for over 1,000 hours at 600 rpm.

The contact system includes three slip rings and three circling rows of contacts including a 90-point inner row, and two outer 180-point rows. The individual contacts employ an exclusive rectangular design and are molded to within an accuracy of 0.005 inch. Innermost row contacts are 0.0315 inch wide; middle row contacts are 0.021 inch wide; outer row contacts are 0.0275 inch wide. Thus a greatly increased number of low level signal contacts available in an accurately reproducible, dimensionally stable, finely miniaturized plate is added to the design potential of PDM systems for guided missile telemetry. Another feature of the switch is a new brush holder design which permits lower pressures on the hard-gold wipers yet which gives low contact resistance with no brush bounce and less wear resulting in longer life.

Circle No. 228 on Inquiry Card

Constant-Torque Spring Motors

In contrast to previous motor designs that employ single NEG'ATOR springs and exert cable retracting forces of 6 oz and 1 and 2 lb respectively, Hunter Spring's new motor package contains two NEG'ATOR constant-force springs to provide increased output torque. Each stainless steel spring is mounted on a separate nylon take-up drum but both exert torque about a single, larger diameter output drum, upon which a pulley and its stainless steel cable are mounted. The dual-spring motors have constant output torques of 2.33, 3.12 and 3.90 lb in. throughout 15 revolutions of the output drum. They provide a constant retracting force of 3, 4 and 5-lb respectively through the full 6-ft cable extension. Endurance of the new motors is 4,500, 3,000 and 2,000 minimum complete operating cycles respectively. All three motors have the same overall dimensions. Each is mounted upon a 2½ x 3¾-in. black plastic base. Because the two take-up spools overhand the base, the total width of the motors is 3-in. They are 1.2-in. high. A stop mechanism holds the stainless steel cable in the fully retracted position when it is not extended.

The units may be used as a design tool by engineers, or for actual application to counterbalance or retract light loads through long deflections without force buildup. Price $12.00. NEG'ATOR Div., Hunter Spring Co., Lansdale, Pa.

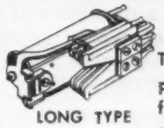
Circle No. 229 on Inquiry Card

CIRCLE 39 ON INQUIRY CARD

RELAYS Thousands of Different Types — Most Makes

OVER 1,200,000 IN STOCK
PRODUCTION QUANTITIES IN STOCK

TELEPHONE TYPE RELAYS


LONG TYPE

The Telephone Type Relay is the basic all-purpose relay. It is suitable, in its various modifications, for the majority of all applications. It may be mounted in any position and operation is not affected by reasonable vibration. Manufacturing facilities available to us enable us to give prompt delivery of these types of relays in any quantity to your specification. In addition, we have a large supply of interchangeable coils and frames in stock. Let us quote on your requirements.

SMALL TYPE—Compact, versatile multiple contact, vibration and shock-proof, these relays are approximately half the size of the more familiar long telephone type. They are similar to the latter in design and operation. Clare type J, Automatic Electric type E, and Phillips type 8QA are included in this group.

SMALL TYPE

WRITE OR PHONE WAlker 5-9257
FOR YOUR RELAY REQUIREMENTS

Among the wide variety of
RELAYS • SOLENOIDS • CONTACTORS • STEPPERS, ETC.
which we have in stock, we can usually fill every need. When inquiring, give as much information as possible.

ALL MERCHANDISE IS GUARANTEED AND MAY BE RETURNED FOR FULL CREDIT

Universal RELAY CORP.
42 WHITE ST., NEW YORK 13, N. Y. • WAlker 5-9257

SEND FOR LATEST CIRCULAR EM

CIRCLE 40 ON INQUIRY CARD

. . . Kearfott analog-to-digital converters

accuracy, reliability, varied capacities and codings

Kearfott's direct drive converters translate shaft rotation into electrical and visual digital form. These mechanically positioned units consist of coded drums, the number depending on the code and total count. The first, or units drum, connects directly to the input shaft and rotates as the shaft turns. On models where more than one drum is used, high speed odometer type gearing provides interconnection. All models can be read "on the run" or "on demand" and all tracks may produce simultaneous or serial readings, depending on the interrogating pulse.

The high performance and quality of Kearfott's analog-to-digital converters are assured by stringent testing for:

Mechanical Accuracy: The location of any code transition point must fall within one-third bit of its true angular position.

Low and High Temperature: All units operate efficiently at temperatures ranging from − 65° F to + 260° F.

Brush Skip: Conducted in conjunction with tests for temperature, vibration, shock and acceleration. A typical brush skip test employs 200 μsec., 23V DC amplitude interrogating pulses at 4000 cycles per second. With the shaft rotating, each output drum track is monitored for a total of 500,000 pulses, in which "lost" counts or "skips" will not exceed 1 in 15,000.

Shock: Kearfott converters are subjected to 18 shocks in three different planes with shock loading of ± 15 g's.

Vibration: Units must withstand vibrations between 5 and 500 cps with applied load of ± 10 g's.

Acceleration: All units are subjected to radial accelerations of varying magnitudes up to a maximum of ± 7.5 g's.

Life: Over 1 million linear feet (1000 hours at 82 RPM) of continuous brush travel on drum coded patterns can be achieved without excessive wear to drums, brushes or other sub-components.

Write for new ADAC brochure.

ANALOG-TO-DIGITAL CONVERTER CHARACTERISTICS

Kearfott Unit No.	423830-1	423607-1	Y1241-11A	P1240-11A	Y1240-11A	U1240-11	P1241-11A
Code (1)	B.D.	B.D.	B.D.	B.D.	B.D.	B.D.	C.B. (Gray)
No. of Drums	1	1	2	3	3	4	5
Range	0 to 84 in 348.5° of arc. 11.5° dead spot coded O	−19 to 0 to + 19	0 to 359	(+) 0 to (+) 999 (−) 999 to (−) 0	0 to 359.9	0 to 359.9	0-32,768 (2^{15})
Bits per Revolution	85	39	40	20	40	40	16
Revolutions for Total Range	1	1	9	100	90	90	2,048
Volts D.C.	23	12	23	23	23	23	10.5
Current (ma.)	20	20	20	20	20	20	20
Inertia (gm. cm.²) (2)	158	48	104	28	158	100	20
Unit Diameter (in.)	2⅛	1¾	1 15/16	1 1/16	1 15/16	1.875	1 1/16
Unit Length (in.)	31/32	1 1/16	1-43/64	1 15/16	2 1/16	2.8125	3
Life (3)	10^6 revolutions or 10^3 hours						
Static Torque (in.-oz.) (4)	0.5	0.1	1.0	.5	1.0	1.0	2 (break) 1 (running)
Weight (oz.)	5	3.5	5.75	4	7.75	6.5	5
Maximum Speed (RPM)	1100	250	300	400	300	700	600
Dielectric (Volts DC)	500	500	500	500	500	500	500

(1) B.D. (Binary Decimal), C.B. (Cyclic Binary).
(2) Inertia measured at maximum trip.
(3) Under recommended conditions.
(4) At room temperature.

Engineers: *Kearfott offers challenging opportunities in advanced component and system development.*

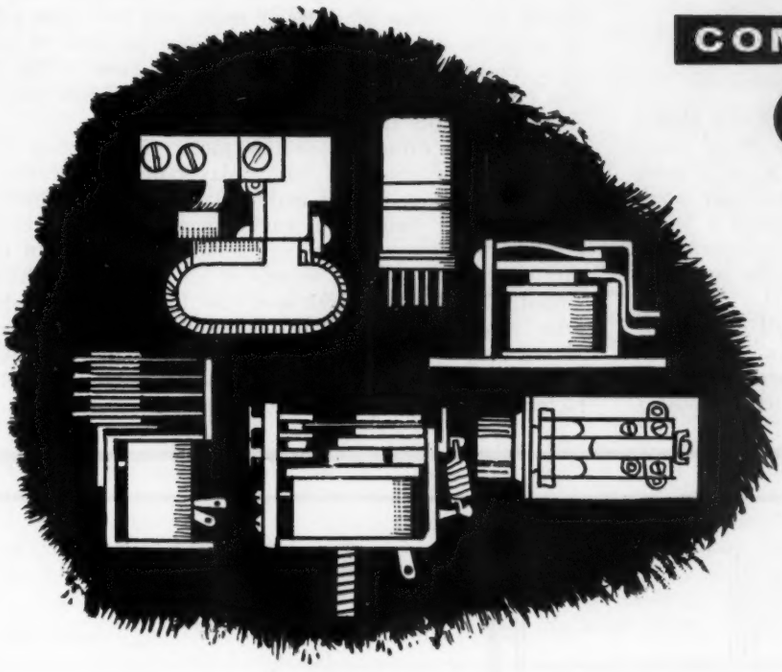
Kearfott — A GENERAL PRECISION COMPANY

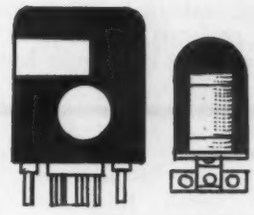
KEARFOTT COMPANY, INC., LITTLE FALLS, N. J.
A subsidiary of General Precision Equipment Corporation
Sales and Engineering Offices: 1500 Main Ave., Clifton, N. J.
Midwest Office: 23 W. Calendar Ave., La Grange, Ill.
South Central Office: 6211 Denton Drive, Dallas, Texas
West Coast Office: 253 N. Vinedo Avenue, Pasadena, Calif.

CIRCLE 41 ON INQUIRY CARD

COMPONENTS 5

DIGEST





Sensitive Relays

The purpose of each Components Digest is to function as a handbook and buyers guide for a class of widely used electromechanical devices. Fulfilling this purpose in the space allotted demands careful limitation of the subject. For this reason Components Digest 5 is limited to magnetically actuated sensitive relays of the armature type.

Relays are electromechanical devices in which the opening and closing of electrical contacts is governed by the application of control signals. Relays may be actuated by either magnetic or electrostatic forces. Magnetic forces are by far the more important.

Depending upon the nature of the actuating signal, relays may be classified as ac or dc. Polarized relays are d-c devices in which the closure of the contacts depends upon the polarity of the input signal. Relays are flexible devices with the greatest variety of contact arrangements and response patterns. Larger relays with heavier or more contacts generally require a greater actuating power than light relays.

A sensitive relay is one actuated by very low power. As yet the industry does not agree on the upper limit of this power. For our purposes, a sensitive relay will be one actuated by 100 mw or less. The most widely used sensitive relay is the armature type defined in Table I. Meter type sensitive relays are sufficiently different to require separate treatment. Thus the subject of this Digest constitutes only a portion of the broad subject of electrically actuated switching devices. Future Digests will cover other varieties of relays and semi-conductor and electronic switching devices.

Sensitive relays are used for control purposes in which relatively small amounts of contact power (below about 100 watts) are handled. Some special purpose types, such as mercury contact relays can handle much larger amounts of power. Where greater capacity is required, control relays may in turn actuate power relays. Sensitive relays may be energized from sources having relatively small power capacity, such as photocells, thermocouples, servomechanism null circuits and miniature transistor amplifiers. For good sensitivity, friction forces in the moving armature and spring restraining forces must be minimized. The number of controlled circuits is kept small. Minimizing the mass of moving parts makes for relatively fast response, a desirable feature in most control applications. On the other hand, the requirement of sensitivity to small input signals (small magnetic forces for actuating the contacts) means critical adjustment, higher manufacturing costs, reduced reliability and sensitivity to difficult environments, particularly vibration and shock. To meet the difficult environments characteristic of guided missiles and space vehicles, *balanced armature* relays are used. Manufacturers are currently devoting a great deal of effort to improving the reliability of sensitive relays.

Excellent sensitivity, down to small fractions of a microwatt, may be combined with ruggedness by packaging an amplifier in the same container as the relay. This package is particularly attractive in view of the miniaturization possible in solid state amplifiers and the improved reliability of these amplifiers at high

COMPONENTS DIGEST

SENSITIVE RELAYS

covered in detail in the succeeding portions of this Digest.

Unfortunately, the absence of a complete set of standards suitable for new critical applications is an obstacle in preparing specifications. The application engineer would do well to spend the time necessary to prepare a totally unambiguous specification which cannot be misinterpreted. For this purpose, reference may be made to the suggested definitions of the National Association of Relay Manufacturers partially listed in Table I. As with all other components, relay specifications must constitute a compromise among reliability, performance and price. Unrealistic specifications for any of these can wreak havoc on the others.

temperature. As long as the amplifier does not itself introduce reliability problems or add excessively to the bulk or weight of the package, it can contribute a decided net gain in performance since it makes substantial power available for relay coil energization. Costs, however, may increase by a factor of three or more over the basic relay. A magnetic amplifier output stage may be used in place of a transistor driver. From the point of view of the user the control windings of the magnetic amplifiers may be indistinguishable from relay windings.

Among the principal selection factors in applying sensitive relays are choice of basic relay type, specification of adequate contact ratings and contact life, coil sensitivity and response time, and environmental factors. Proper relay application requires consideration of means of contact protection, and the design of an appropriate driving circuit. The driving circuit is a vital factor in establishing relay response time, the principal time delays occurring in the coil. In closed loop control systems the differential signal for actuation and release of contacts is an important factor in establishing stability. These and other topics are

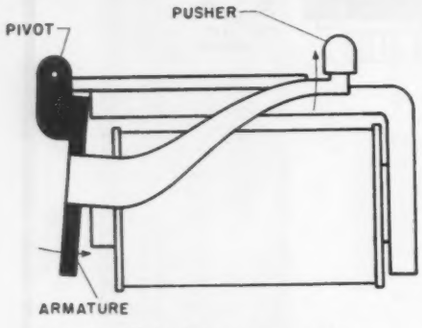


Fig 1—Telephone type structure

BASIC RELAY PARTS

Figure 1 shows the essential parts of a general purpose relay with a single, normally open, contact. The basic parts are a magnetic structure, a winding, and contacts mounted on springs. The winding and magnetic structure convert the electrical input power into motion to actuate the contacts. The magnetic structure consists of a fixed portion, including the energizing winding, and a movable portion, called the armature, held in its normal position by a restraining spring (sometimes a permanent magnet bias is employed). The magnetic circuit is made of soft magnetic iron, and forms a closed path, except for an airgap between the fixed portion and the armature allowing movement of the armature on application of a magnetotive force. The pull is concentrated in the airgap and the motion of the armature closes the gap. General purpose relays include the elements of Fig. 1. Construction and appearance of specific relays vary. Figure 2 shows balanced armature types more suitable for vibration environments. Figure 3 shows a rotary armature type, suitable for high vibration and shock.

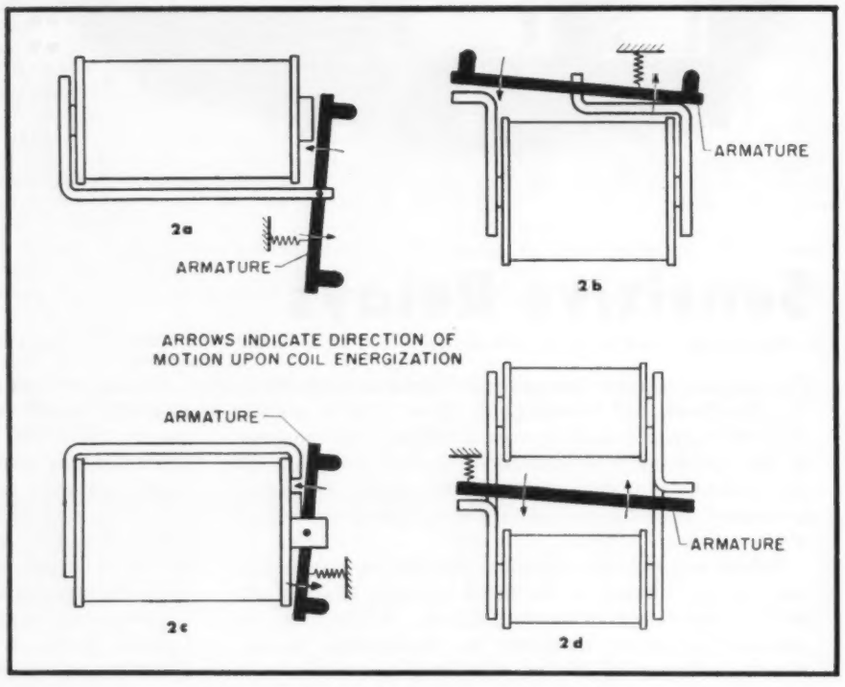


Fig 2—Typical balanced armature designs

MAGNETIC CIRCUIT FUNDAMENTALS

Many relay behavior characteristics are best understood in terms of simple magnetic circuit concepts. Consider the relay configuration of Fig 1 as a basic structure on which to apply our reasoning.

● Assume d-c excitation. By applying the basic laws of the magnetic circuit the following conclusions may be drawn:

● Power required to energize a given relay is independent of the turns in the relay coil as long as the full volume of the coil is filled with wire.

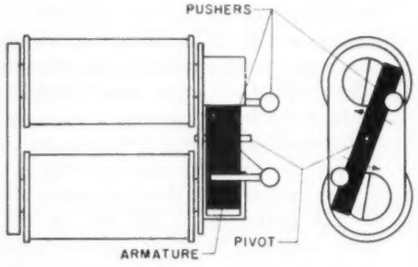


Fig 3—Rotary armature type

● Time constant (L/R) of a given relay coil is independent of the turns as long as the full coil volume is filled with wire.

● Reluctance of the magnetic circuit decreases as the armature moves to close the gap, increasing the coil inductance and time constant. The effect is most pronounced in the efficient magnetic circuits of sensitive relays.

As a result of this decrease in magnetic circuit reluctance, magnetizing power required to hold a relay is appreciably less than that required for initial energization.

Residual magnetism may tend to hold a magnetized relay, increasing the differential between "actuate" and "release" signals. Again this effect is greatest in sensitive relays having efficient magnetic circuits. Residual magnetism is least in carefully annealed high permeability magnetic steels.

The force relationships are described in Figs 6 and 7.

A-C VS D-C RELAYS

A relay responds basically to the *ampere-turns* applied to its excitation coil. Relays excited from a-c signals have control power sensitivities of the same order of magnitude as d-c relays, with some additional power required for eddy current losses in the magnetic path, and in the shading coil slug used to achieve a more uniform magnetic pull. A-C relays may be energized satisfactorily on d-c with a slowed up response due to the shading coil. Because of the reactive nature of the relay coil, however, the mv-amperes required for operation may exceed the mw by a factor of three or more.

The operation of an a-c relay is further complicated by the large increase in coil reactance which can occur upon closing of the armature airgap. Consider a slowly increasing control voltage applied to the relay coil. At a given point, excitation is sufficient to initiate motion of the armature and closing of the airgap. However, as the gap closes, reactance rises sharply, cutting the current (and ampere-turns) delivered from the a-c line, to a point insufficient to maintain the closed position, the armature opens, the process is repeated, and the relay chatters. This problem is overcome by applying an excitation considerably greater than that required to initiate operation. A superior approach, where practical, is to employ constant current excitation; energizing the relay from a high resistance source, such as a line dropping resistor, or a pentode. There have been instances, however, where fast operating relays operating in the constant current plate circuit of a pentode have had punctured insulation resulting from the rapid build-up of coil voltage due to the abruptly increased inductance of the closing armature.

A-C relays may also be operated from a set of rectifiers, a full wave bridge being a common arrangement. The size of new semi-conductor diodes has been so reduced that they constitute a negligible increase in the overall bulk. Relays of this type have essentially the same sensitivity as d-c relays, except for the slight losses in the rectifiers. High speed relays may tend to chatter as a result of the double-frequency ripple introduced by the full-wave rectification. This is naturally a much more severe problem where 60 cycle line is used, than for 400 cycle line. A shading coil over a portion of the core facing the armature, as for an a-c relay, will eliminate this chatter, although it introduces time delay. A similar time delay would be introduced by filtering out the excitation ripple component.

POLARIZED RELAYS

Polarized relays are d-c units whose energized contact position depends upon the polarity of the coil signal. They employ a permanent magnet which generates a steady magnetic field. At one point a pair of alternate paths for the magnetic flux are provided, the choice of which depends upon the armature position. Energizing the relay coil polarizes the armature, in accordance with the d-c signal polarity, causing it to switch to the appropriate position. This type of relay can be made very sensitive because the permanent magnet flux is merely *switched* and the total magnetic energy doesn't change much. Figure 4 shows a variety of possible magnetic circuits for polarized relays, which operate on similar principles. A restraining spring may hold the armature in "neutral" position in the absence of an applied excitation. Biasing the restraining spring shifts zero to any arbitrary point of operation where some special applications may require.

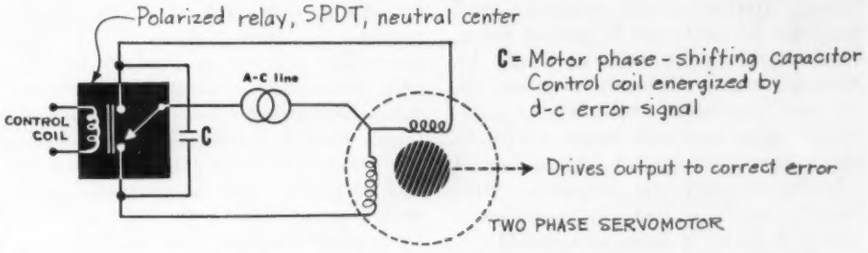


Fig 5—Polarized relay in servo loop

Polarized relays are most suitable for relay servomechanisms where sensitivity to polarity is a necessary feature of performance. Their high sensitivity makes them frequently usable without additional preamplification. Figure 5 shows a polarized relay used in a servo driving a 2-phase a-c motor. For this type application the differential between "operate" and "release" must be minimized to achieve good closed loop stability without chatter. However, a minimum differential can only be achieved through sacrifice of other performance factors, particularly good

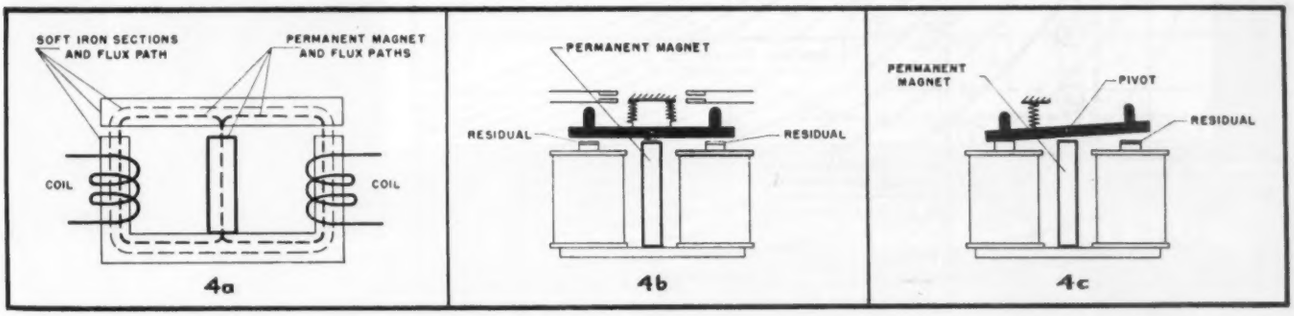


Fig 4(a)—A basic magnetic circuit arrangement for polarized actuator

Fig 4(b)—Polarized neutral center relay

Fig 4(c)—Polarized relay for pull-in drop-out operation

COMPONENTS DIGEST

SENSITIVE RELAYS, Cont.

contact pressure and snap-action operation. Polarized relays have been developed by Sigma which include an extra coil and contact, so arranged and energized that upon closing of contacts, a bucking voltage is applied to the relay coil so that it approaches the release condition, and vice versa on opening. The differential may be made to approach zero by this means. The principle limitation of this method appears to be that the normal variation in relay behavior during use, and under varying conditions, necessitates leaving an adequate margin in adjusting the relay differential.

The permanent magnet within the relay case introduces an external field which can be readily detected. Accordingly, it is necessary to so orient and locate the relay as to minimize interaction with ferrous materials or magnetic sensitive devices in the vicinity. Similarly, the magnet itself must not be subjected to intense fields, even momentarily, such as might be caused by a brief heavy overload on its own excitation coil. Where adjacent ferrous materials cause a shift in relay operating point, some circuit adjustment may be required after installation. This can be troublesome where it had not been anticipated.

RELAY PERFORMANCE, GRAPHICAL ANALYSIS

The curves of Fig 6 show, for different values of coil input wattage, the magnetic force developed at the gap between the armature and the pole of the magnetic core, as this gap is varied from zero to twenty-five thousandths of an inch. Since the armature is pivoted half way between the contacts and the pole gap, the force developed at the contacts will be exactly equal to the force shown on the curves—minus the force developed by the spring which acts in the opposite direction. Naturally, if the spring force is greater, the resulting pressure will be developed on the normally closed contact—the one which is closed when no current is applied to the coil. This contact is lettered "B" in Fig 7, which shows the salient aspects of a Sigma Series 4 sensitive relay. Note in Fig 7 that the armature motion allows the pole gap to vary from G_n to G_e. Two vertical lines on Fig 6 at points along the horizontal axis represent G_n and G_e. A horizontal line drawn from a point on the vertical axis represents the spring force.

Before current is applied to the coil, the spring holds the armature in the position G_n with a force of "A". As increasing current is applied to the coil, an increasing magnetic force opposes this spring force. When the coil power reaches a value of 40 milliwatts, the graphs shows at point (1) that in this particular case the magnetic force will have exceeded the spring force by a small amount. The result is that the armature rotates to the other extreme of its travel (the relay "pulls on") and the pole gap becomes equal to G_e. With the gap at this value and the coil power still 40 milliwatts, the graph shows at point (2) that the magnetic force exceeds the spring force by an amount equal to the distance from point (2) to point (3). This amount is, then, the contact pressure developed on the normally open contact (Fig 7) when the relay has just pulled on.

Now let the coil power be decreased; when it has dropped sufficiently low the magnetic force becomes slightly less than the spring force, the spring restores the armature to its original position, and the relay "drops out". The coil power value at which this occurs is indicated by point (3) which is a point on an interpolated curve yielding force A at a gap equal to G_e. The power value of this curve is estimated from its position with respect to given curves, and is the drop out value for the adjustment under consideration.

When the armature drops out, restoring the gap to the value G_n, the magnetic force is determined by point (4), the intersection of the interpolated curve passing through point (3) with the vertical line at gap G_n. The contact pressure immediately after drop out then equals the difference between the magnetic force given by point (4) and the spring force A, shown at point (1). As the current decreases further toward zero, the contact pressure on the normally closed contact (B Fig 7) approaches the value of A. The cycle has now been completed.

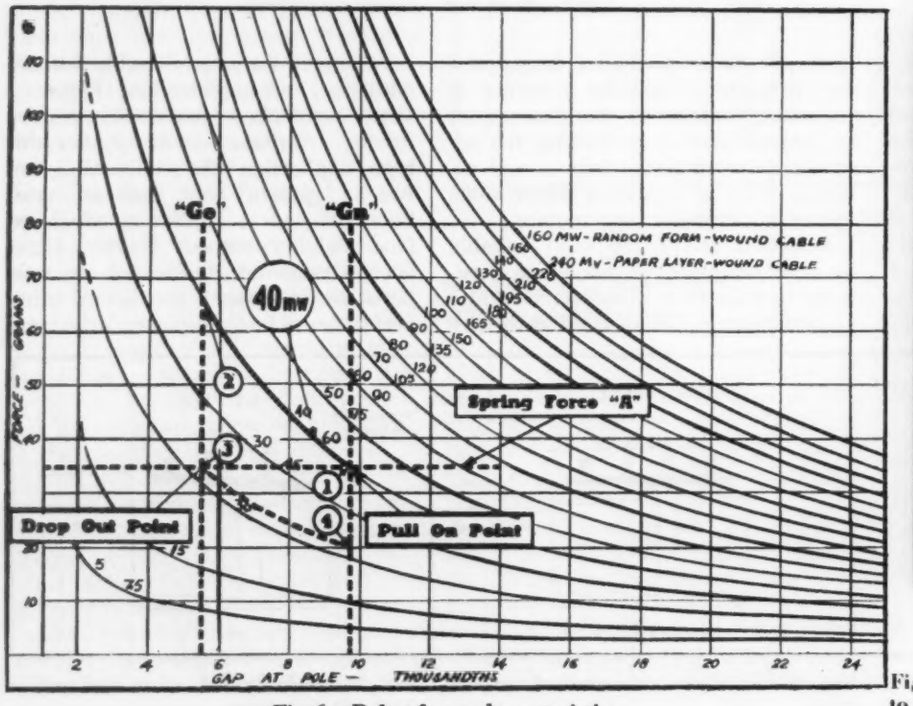


Fig 6—Relay force characteristics

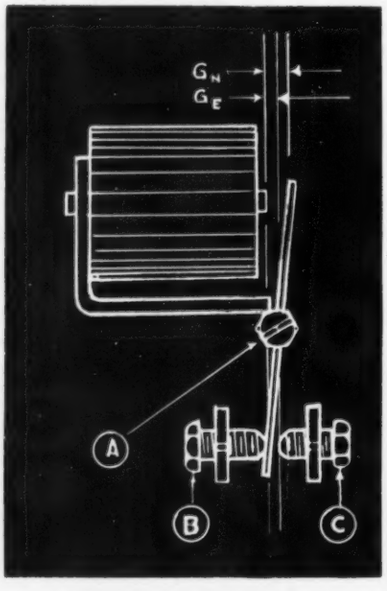
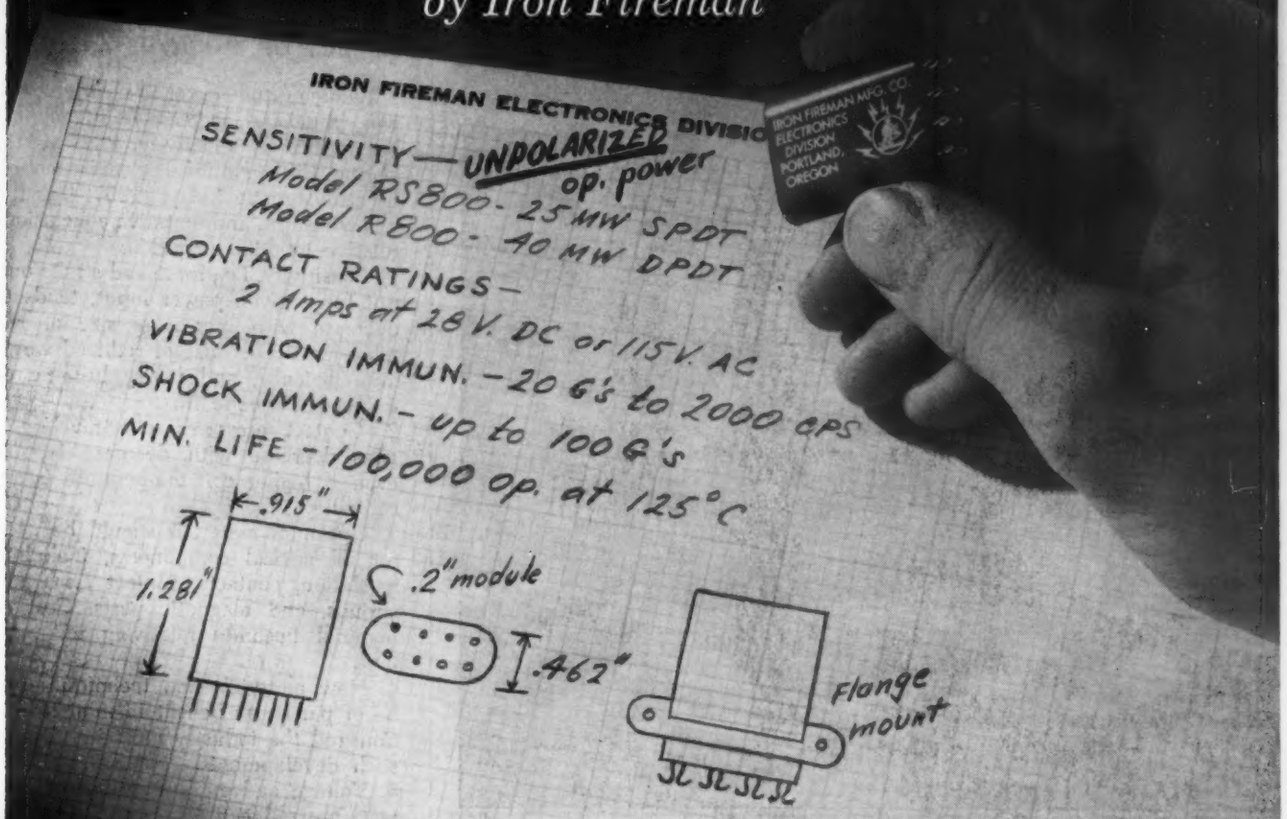


Fig 7—Relay configuration referred to in Fig 6

Now MICRO-MINIATURE SENSITIVE RELAYS

by Iron Fireman


IRON FIREMAN ELECTRONICS DIVISIO
SENSITIVITY— UNPOLARIZED op. power
Model RS800 - 25 MW SPDT
Model R800 - 40 MW DPDT
CONTACT RATINGS—
2 Amps at 28 V. DC or 115 V. AC
VIBRATION IMMUN. - 20 G's to 2000 CPS
SHOCK IMMUN. - up to 100 G's
MIN. LIFE - 100,000 op. at 125°C
.915"
1.281"
.2" module
.462"
Flange mount
IRON FIREMAN MFG. CO.
ELECTRONICS DIVISION
PORTLAND, OREGON

Sensitivity down to 25 mw.

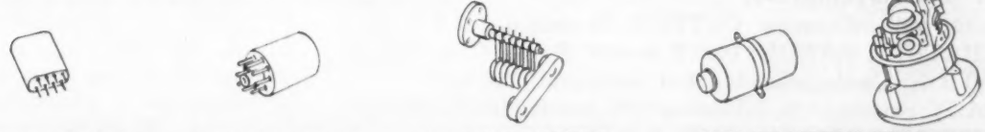
The sensitivity ratings, vibration and shock immunities shown above are achieved for the first time in a micro-miniature package.

Where only limited power is available, the Iron Fireman R800 offers sensitivities as low as 25 MW of unpolarized exciting power and a high degree of reliability and environmental immunities.

Conforming to and exceeding the test requirements of MIL-R5757C, the performance and reliability of this relay is further enhanced by separately sealing the coils within the outer shell.

Complete performance data available on request. Write to the address below.

When space, weight and sensitivity are a problem specify the Iron Fireman R800 Relay



MICRO. MIN. RELAYS | HIGH SPEED RELAYS | SLIP RINGS & BRUSHES | FREE AND VERTICAL GYROS

IRON FIREMAN *Electronics* DIVISION

2838 S. E. NINTH AVENUE, PORTLAND 2, OREGON

CIRCLE 42 ON INQUIRY CARD

NEW WESTINGHOUSE LIMITEMP
Indicating Temperature Control

Limitemp* is a new, medium-priced control device that is ideal for monitoring or controlling temperatures between 100° F and 400° F. Controller may be used to indicate temperature and sound an alarm if temperature exceeds the preset point. A few applications include windings of large rotating machines, bearings, process temperatures and controlling temperatures in critical areas such as nuclear controls.

Limitemp employs magnetic and semiconductor elements of proven reliability; therefore, no vacuum tubes, no moving parts, no contacts . . . nothing to wear out.

LIMITEMP CHARACTERISTICS:

INPUT: 115 volts, 60 cycles OUTPUT: 24 volts d-c at 5 watts
TEMPERATURE RANGE: 100° F to 400° F—40° C to 200° C
INDICATION: Dual-scale calibrated meter and pilot light
ACCURACY: Setting ±1%, indicating ±2%, bandwidth 2% of range
COMPACT: 4 in. wide, 8½ in. high, 6 in. deep

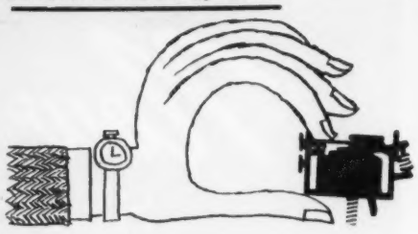
GET ALL THE FACTS . . . write Westinghouse Electric Corporation, Director Systems Dept., 356 Collins Avenue, Pittsburgh 6, Pa. Complete information on the new Westinghouse Limitemp will be sent to you by return mail. J-01008

*Trade-Mark

YOU CAN BE SURE . . . IF IT'S Westinghouse

WATCH "WESTINGHOUSE LUCILLE BALL-DESI ARNAZ SHOWS" CBS TV MONDAYS

CIRCLE 43 ON INQUIRY CARD



EFFECT OF MINIATURIZATION

Reducing the size of a sensitive relay will, in general, increase its ruggedness but reduce its sensitivity. P.N. Martin at the Fifth National Conference on Electromagnetic Relays, 1957, lists the following firm and tentative conclusions relative to miniaturization:

1. Sensitivity, i.e., force and stroke output for a given power input, tends to decrease with increasing size of the relay, partly because of reduced winding efficiency, and partly because of reduced magnetic flux.
2. Contact pressures, overtravel, and gaps decrease with decrease in size even if higher coil temperature is accepted.
3. Optimum materials should be used for all critical components, including insulation, contacts, contact arms and springs, and magnetic parts. Cost of material becomes relatively unimportant.
4. New materials and techniques can be of particular benefit in miniaturization and the industry must be alert to such developments.
5. Voltage and current ratings of contacts are reduced, although it is often possible to avoid this by reducing the number of contacts on the relay.
6. The smaller the size, the more important it becomes that the whole design, including magnetic circuit and contact structure, be fundamentally sound.
7. Operating time can be reduced by miniaturizing, in proportion to the reduction in linear dimensions or more.
8. Resonant frequencies of parts and assemblies are increased approximately in inverse proportion to the linear dimensions of the relay.
9. Difficulties in manufacture and manufacturing costs are a principal limitation in miniaturization.

Mr. Martin presented the following additional conclusions as personal opinions that perhaps have not been completely substantiated.

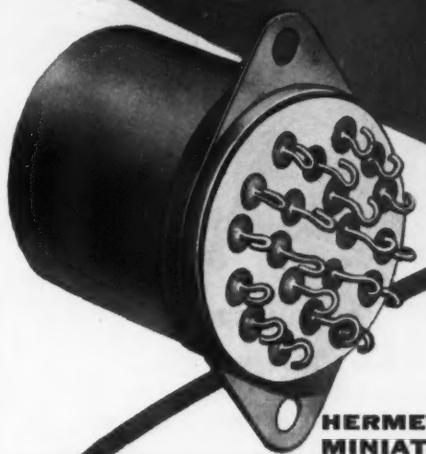
10. The calculated characteristics obtained by a theoretical scaling-down of a sound relay design provide a good basis for estimating the possibilities of miniaturization and for comparison with the designs resulting from a miniaturization design project.

11. The scaling-down technique provides a relatively simple method of predicting characteristics because any dimension can be related to any selected linear dimension by a constant of proportion for the full-size design, and another constant K for the reduction in size. Thus formulas that normally involve several dimensions, such as width, thickness, and length, can be written in terms of a single linear dimension and the various constants.
12. A design that works out well in a miniaturized version is likely to be fundamentally sound and will be a good design also if made to a larger scale for heavier duty.
13. Conversely, if a type of design cannot be made to work well in a miniature size in comparison with others, probably it is inherently weak and might well be replaced in larger sizes also.
14. Miniaturization increases the problem of maintaining reliability of product. A manufacturer should be able to produce a relay of high reliability in a moderately small version before undertaking to produce a miniaturized version.
15. Winding efficiency in a scaled-down design, as measured by the figure of merit, which is N2/R, is directly proportional to K, the reduction multiplying factor.
16. The wire diameter for a coil to operate on the same voltage is reduced by the multiplying factor K. The wire becomes one gage finer for a 10 percent reduction in coil size ($K = 0.90$).
17. Magnetic force in a scaled-down design is proportional to K^2 at stroke distances proportional to K. For a rotary device magnetic torque is proportional to K^3 at the same angualr stroke.
18. The time constant of a scaled-down winding is proportional to K^2. This is an indication of the retardation time that can be obtained on drop-out by using rectifier or resistor snubs or shorted turns, as well as of the decrease in time of build-up or collapse of current in normal operation.
19. In a scaled-down contact design, the voltage rating should be reduced approximately in proportion to K and the current rating to $K\ (K)^{1/2}$.

CONTACT ARRANGEMENTS

The flexibility of the relay as a control device is markedly enhanced by the variety of possible contact configurations. In the majority of instances the open and energized armature positions are readily adapted to normally opened or normally closed contacts, the number of such contacts depending upon the design of the relay and available

SIMPLE DESIGN
HIGH RELIABILITY
...and PRICE-RIGHT



Style 520
GENERAL PURPOSE RELAY

HERMETICALLY SEALED
MINIATURE - 6 PDT

Simplicity of design and perfect performance make the Style 520 an ideal, low cost, high reliability relay for general purpose and low level circuit use.

Produced in pressurized, dust-free rooms to prevent contamination, the 520 is quality-controlled from order through production.

Meets the following specifications and drawing:

MIL-R-5757C
MIL-R-25018 (USAF)
MS24115-6 (USAF) Class B;
Type II, Grade 3

Let Price stepped-up production and service solve your relay problems.

GENERAL CHARACTERISTICS
For 26.5 VOLT OPERATION

CONTACT ARRANGEMENT	Six Pole Double-Throw (6 Form C)
COIL RESISTANCE (Nominal)	240 Ohms (at 25° C)
MINIMUM CONTACT PRESSURE	25 Grams on N.C. Contacts 35 Grams on N.O. Contacts
CONTACT CAP	0.010"
OPERATING TIME	10 Milliseconds maximum at 26.5 Volts, 25° C.
DROP-OUT TIME	7 Milliseconds maximum at 26.5 Volts, 25° C.
AMBIENT TEMPERATURE RANGE	—65° C. to plus 125° C.
VIBRATION	15 G to 2,000 c.p.s.—no contact chatter, 20 G if specified.
SHOCK	50 G, 11 Milliseconds—no contact chatter.

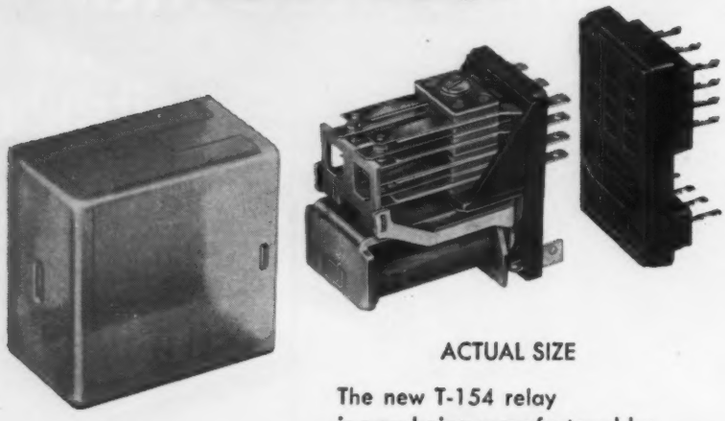
For further details, call or write for Bulletin 12

PRICE ELECTRIC CORPORATION
Frederick, Maryland MOnument 3-5141

PRICE ELECTRIC CORP. FREDERICK, MD. HUSKY RELAYS · CONTROLS

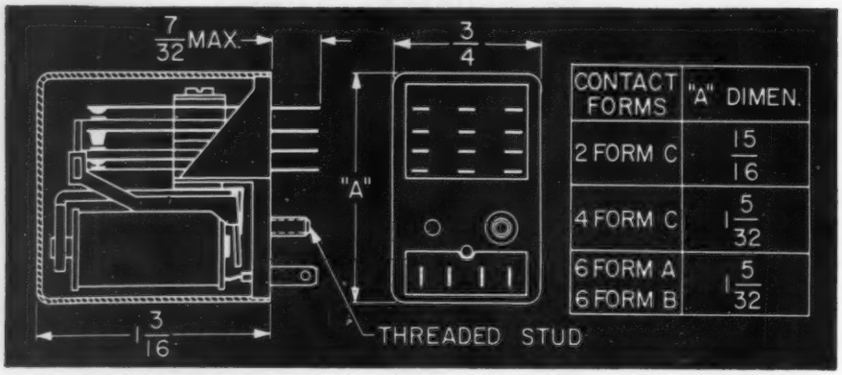
CIRCLE 44 ON INQUIRY CARD

MINIMUM SIZE
Maximum Dependability
LOW COST



ACTUAL SIZE

The new T-154 relay
is now being manufactured by
Allied Control at Plantsville, Conn.



CONTACT FORMS	"A" DIMEN.
2 FORM C	15/16
4 FORM C	1 5/32
6 FORM A 6 FORM B	1 5/32

General Features:

Operate Sensitivity:
From 90 milliwatts for 1.3 ohm coil to 160 milliwatts for 15,000 ohm coil up to 2 Form C
From 200 milliwatts for 1.3 ohm coil to 400 milliwatts for 15,000 ohm coil up to 6 Form A

Coil Resistance: Up to 15,000 ohms

Coil Voltage: Up to 140 volts d-c

Contact Rating:
Low Level to 1 ampere 29 volts d-c or 115 volts a-c resistive.
5 ampere contacts are available

Contact Arrangement: Up to 6 Form A, B and 4 Form C

Operate and Release Time: 7 milliseconds max. at 1 watt

Shock: 10 g's

Vibration: 10 to 55 cps at .062" double amplitude

Enclosure: Dust proof and hermetically sealed

For complete information write for Bulletin T154

ALLIED CONTROL

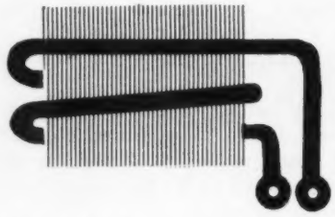
ALLIED CONTROL COMPANY, INC., 2 EAST END AVENUE, NEW YORK 21, N. Y.

AL 193

CIRCLE 45 ON INQUIRY CARD

control power. Since the individual contacts require a specific contact pressure for reliable operation, the required magnetic pull on the armature must increase with the number of contacts. Table I shows some of the possible contact arrangements suggested by the National Association of Relay Manufacturers.

During relay operation, because of the finite transit time of the armature, contacts open or close in a somewhat random sequence. This phenomenon is accentuated in slow speed relays. This random contact response must be analyzed to observe the effects on circuit operation, particularly transients. Momentary short-circuits of the power source may occur to erode contacts and cause possible circuit damage.



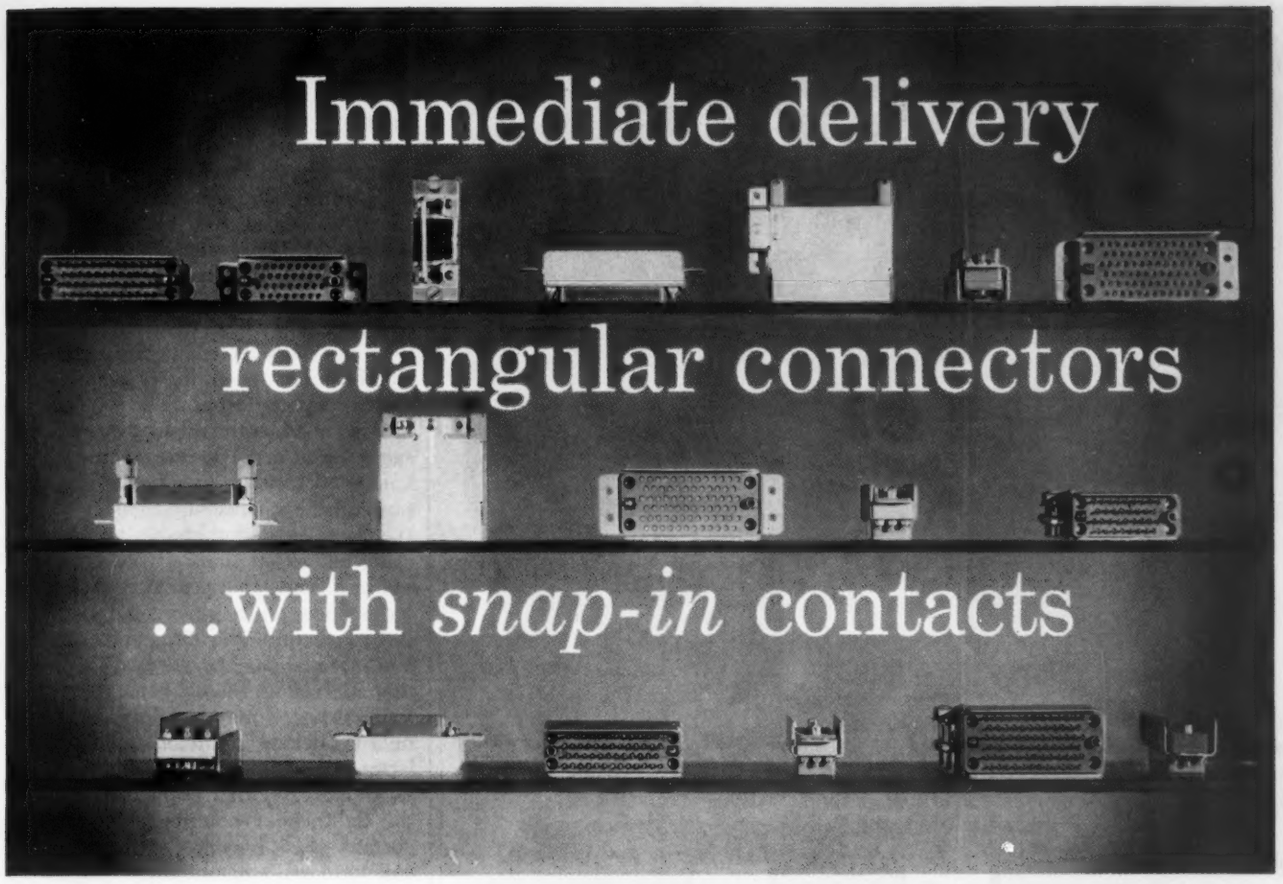
RELAY COILS

Relays are available with a variety of windings to meet special requirements. Single coil windings may be prepared in a wide range of resistance values to match circuit impedance and voltage levels. High impedance windings are limited by the fineness of the wire that can be economically and reliably used, as well as insulation requirements corresponding to the high voltages for coil energization. Wire up to about size 50 (1 mil in diameter) is practical.

Where the winding coil form is completely filled, d-c resistance varies approximately as the square of the number of turns, just as does winding inductance. Thus, the L/R time constant of the coil, or the power-factor on a-c operation, is unchanged. Sensitivity as measured in mv-a, or mw, is similarly fixed.

At the low voltage end, coil voltage rating is limited by the heavy wire required for coil and lead in wires. The wire may be too stiff for easy handling, although the problem does not often occur. Braided lead-wire and parallel coil conductors help solve this problem.

Additional winding arrangements include multiple windings for separate differential excitation, center-tapped windings for push-pull circuitry, where quiescent d-c is cancelled out by sym-



Available now... CEC electrical connectors in large or small quantities to satisfy an exceptionally wide variety of applications — flush- or surface-mounting types . . . with jack-screws or guide pins . . . straight- or right-angle hoods . . . in 26-, 34-, 42-, 50-, or 75-pin configurations—all standard types with off-the-shelf availability.

Lightweight, rugged, and dependable, the Series 500-C multi-contact connectors feature easy-to-assemble snap-in contacts which simply push into place, yet permit fast, easy removal with a simple hand tool. A triple retention spring in each contact resists an axial pull of at least 20 lbs. – equal to a cable-harness pull in excess of 1,500 lbs. for a 75-pin connector.

CEC connectors represent the newest concepts of design and materials and employ a modular construction to enhance flexibility of application and speed assembly and installation. Individual contacts accept insulated wires from size 20 to 24, and cables composed of wires from 0.054" to 0.10" in diameter are easily accommodated by the connector enclosure. Contacts are gold-plated and can be used with hand, semi-automatic, or automatic crimping methods. CEC connectors exceed the requirements of MIL-C-8384A.

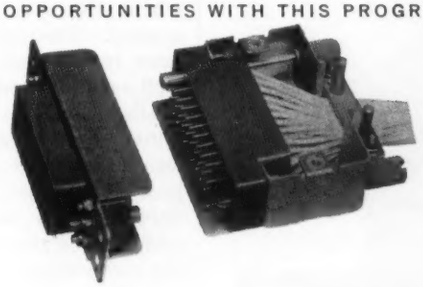
SPECIAL CONNECTORS... If your application requires an unusual or special type connector often demanded by advanced technologies, you are invited to take advantage of CEC's proved experience in the design and manufacture of these custom types . . . designed for the particular application and and environment you specify.

Write today for complete information on Series 500-C connectors, or call your nearby CEC sales and service office. Ask for Bulletin CEC 4004-X13.

Electro Mechanical Instrument Division **CEC**

CONSOLIDATED ELECTRODYNAMICS *300 N. Sierra Madre Villa, Pasadena, Calif.*

FOR EMPLOYMENT OPPORTUNITIES WITH THIS PROGRESSIVE COMPANY, WRITE DIRECTOR OF PERSONNEL



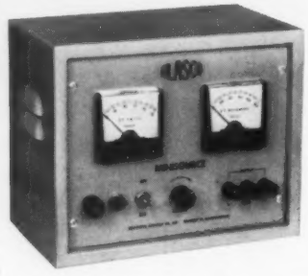
SERIES 500-C CONNECTOR... Removal of portal door exposes interior of connector for contact insertion, removal, or replacement, and allows quick inspection and adjustment of cable-harness.

CIRCLE 46 ON INQUIRY CARD

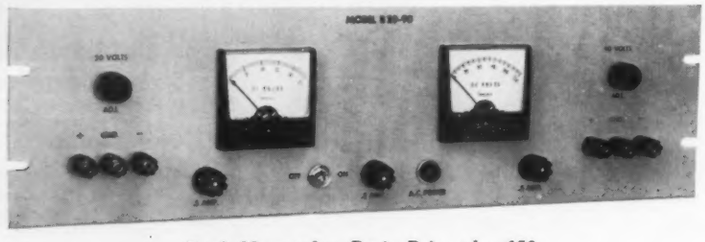
power supplies

100% Serviceable

Transistorized ○ Transformer Cased
3 5/16 x 3 7/8 x 4 1/2 ○ Basic Price: $64 to $127



Lab Model ○ Basic Price plus $60



Rack Mounted ○ Basic Price plus $50

MINISOURCE Power Supplies

100% SERVICEABLE

No Potting
Printed Circuit Design
Accessible Components

Full Wave Bridge
Flexible E&I Ratings
Standard units from 5 to 50 volts at currents from 50 to 500 ma or units designed and built to customer specifications.

INPUT: 105—125 V AC

REGULATION: better than 0.5%

RIPPLE: better than 0.5%

OUTPUT IMPEDANCE: less than 0.25 ohms, DC—100 kc

POLARITY: grounded or floating operation

TEMPERATURE: compensated from —10 to 55C

PRICE RANGE: Indicated below each unit

Send for complete catalogue

Elasco

ELECTRONIC ASSEMBLY CO., INC.

Five Prescott Street, Roxbury 19, Mass.

Highlands 2-1600

CIRCLE 47 ON INQUIRY CARD

metry, so that the relay only responds to appropriate signals. For special purposes, non-inductive windings on the coil form may serve as resistors to be connected in the relay control circuitry much as would an external resistor. For some control applications, a "secondary" winding coupled closely to the primary, for example by bifilar winding, may be used as part of a stabilization network for improved closed-loop operation. Some control relays with an array of windings on the same form may be reconnected in a variety of ways for use in different positions in an instrument, simplifying the spare parts problem.

In all applications involving multiple windings, the presence of mutual inductance must be recognized. This is true in both d-c circuits as well as a-c circuits. In the former, transient mutual voltages are generated, and time response may be delayed by induced bucking currents, while in the latter, operation may be entirely unsatisfactory. With this factor in mind, the tightness of coupling becomes important. Side-by-side windings on a coil form are not as tightly coupled as windings superposed one on the other; "sandwiched" windings, where portions of the separate coils are placed on the form alternately, and bifilar windings give increasingly tight coupling. Insulation between windings may be important, and its need must be evaluated with respect to transient peaks under the worst possible conditions. the importance of the transients cannot be overemphasized; failure to recognize transient problems is undoubtedly a major reason for relay misapplication.

In relays with more than one winding, if all other factors the same, d-c resistance increases approximately uniformly with decreasing coil cross-sectional area. This means more mw required for coil excitation.

In the relay coil itself, wire insulation, coil form, impregnating compound, and other insulating materials must be capable of protecting the winding from corrosion and of withstanding the maxium temperatures to which the coil is subjected without gassing. The maximum temperature must include coil temperature rise as well as heat conducted from the areas of the contacts, although these heat sources are not severe in sensitive relays. In unsealed relays at high altitude, heat convection from the coil is reduced, with a consequent increase in temperature rise. This, as well as arcing, constitutes the chief problem associated with high altitude operation.

HIGH SPEED OPERATION

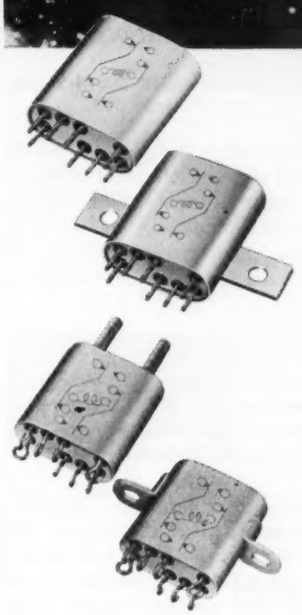
Any inductive device such as a relay will have a speed response which is the sum of the rise (or decay) time of its coil current to the trip value plus the time required for actual contact transfer. The latter tends to be smaller than the current rise time for most relays and circuits, and is in general between 0.5 and 2 milliseconds. The coil current rise or decay time is variable over a much wider range and fortunately is, in general, subject to various treatments which are often capable of leading to fairly major improvement in overall speed of response.

In an inductive circuit, the time of rise of current to 63 percent of its ultimate value (or time of decay to 37 percent of its original value) is given by T-L/R. Sigma Instruments Inc. have found the following steps to be effective in making T as short as possible for a given current change.

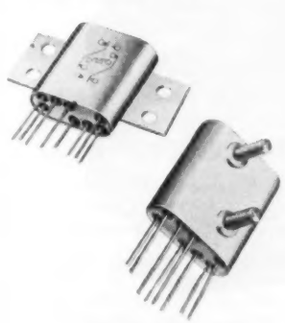
- Obtain the greatest possible difference between the ultimate current value and the actual trip value. This provides what is known as current overdrive and steepens the initial rate of current change.
- Increase the source voltage without increasing the inductance in the circuit. To do this and maintain a chosen value of current means that the circuit resistance must be increased, thereby giving a faster rate of current change (or shorter T-L/R).
- Avoid shunting paths which are resistive or capacitive, and which would permit a considerable phase lag in the immediate relay coil circuit. This applies equally to bias or alternate energizing circuits in second windings. It does not apply to arc-suppression circuits applied to series contacts.
- When relays are driven by vacuum tubes, drastically different results can be obtained from different arrangements of similar components and signal. A cathode follower circuit gains nothing from the high plate voltage and the high plate resistance of the tube as contributing factors to a "stiff" relay drive; likewise, a relay will be faster in the collector circuit of a given transistor than in its emitter circuit when the signal is applied in effect between the base and the emitter.

Sigma engineers also point out that when the problem is to de-energize an inductive load in the shortest possible time, opening a series switch which has no arc-suppression will not stop the load current as quickly as when the proper choice of resistor and capacitor is placed across the contacts. If arcing is prevented, the voltage opposing the current flow quickly rises into the 100- to 300-volt range in contrast to the approximately 12- to 40-volt drop in

crystal can size relays by ADVANCE



ADVANCE MV SERIES
offered in 3 terminal arrangements...6 mounting arrangements, and 7 resistance values (30 to 10,000 ohms).
—AVAILABLE AT ADVANCE DISTRIBUTORS



—these construction features assure exceptional reliability:

Positive sealing. Advance's use of induction heating cuts rejects from faulty soldering to a negligible figure. Soldering is accomplished at high speed, hence damage to the relay due to heat transfer is eliminated.

RADIFLO testing for leakage is used to detect leaks as small as 10^{-8} cc/sec. All relays that pass this test will function after long shelf life.

RIQAP* program approval. Under RIQAP, the Signal Corps constantly checks Advance's quality control and inspection, to insure military standards of reliability for all Advance customers, both military and industrial.

*Reduced Inspection Quality Assurance Plan of the U.S. Army Signal Corps.

SPECIFICATIONS

Coil resistance:	Available in 7 values, from 30 to 10,000 ohms.
Shock:	50 G's for 11 milliseconds.
Vibration:	10 to 34 cycles per second at maximum excursions of .4". 34 to 2000 cps 20 G's acceleration.
Operating power:	Pull in power 250 milliwatts at 25°C.
Contact rating:	2 amps resistive at 32 VDC or 115 VAC.
Life:	100,000 operations minimum at rated current.
Weight:	0.45 ounce.
Size:	7/8" high x 51/64" wide x 23/64" deep.

Our Applications Engineering Dept. will be pleased to work with you on your special application problems.

ADVANCE RELAYS
ELGIN
A PRODUCT OF ELECTRONICS DIVISION
ELGIN NATIONAL WATCH COMPANY
2435 N. NAOMI ST., BURBANK, CALIFORNIA

CIRCLE 48 ON INQUIRY CARD

LOOKING FOR DATA SIGNAL-CONDITIONING EQUIPMENT?

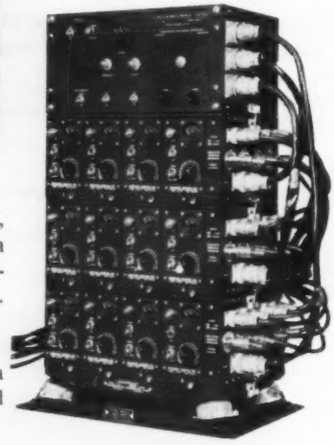
Type 1-127 Carrier Amplifier . . . Four channel 20-kc Carrier Amplifier will accept low level signals in the 0 to 5000-kc frequency range. Write for Bulletin 1550-X1.

These data amplifiers, bridge balances and power supplies are but a part of the most complete and fully integrated line of dynamic data processing equipment available anywhere.

Type 8-108 Bridge Balance . . . Provides coupling and a complete control center between as many as eight strain gages or resistive-bridge-type pickups and recording oscillographs. Four-channel type is also available. Write for Bulletins 1530-X1 and 1560-X24.

Type 1-118 Carrier Amplifier . . . Four-channel, 3-kc carrier amplifier provides frequency response from 0 to 600 cps. Unit features low cost and simplified operation. Write for Bulletin 1522-X12.

Type 3-132 Power Supply . . . Furnishes up to 1 ampere at 0 to 15 volts d-c with extremely high stabilization. Less than 1 millivolt drift in 24 hrs. Available for use with 50/60 or 400 cps power source. Three other power supply types also available. Write for Bulletin 1543-X12.



Amplifier System D . . . Multichannel, dual-purpose, amplifier system provides both linear-integrating and carrier amplifiers. Frequency response ranges from 5 to 5000 cps. Write for Bulletin 1403-X7.

Write for General Catalog 1310-X1 for a more complete description of these and other data processing instruments.

Electro Mechanical Instrument Division CEC

CONSOLIDATED ELECTRODYNAMICS/300 n. sierra madre villa, pasadena, california

FOR EMPLOYMENT OPPORTUNITIES WITH THIS PROGRESSIVE COMPANY, WRITE DIRECTOR OF PERSONNEL

CIRCLE 49 ON INQUIRY CARD

COMPONENTS DIGEST

SENSITIVE RELAYS, Cont.

an arc. Rectifiers, as arc-suppression, permit the current to continue to flow with very low opposing voltage drop, and give the slowest time response.

LOW SPEED OPERATION

Relay response time can be increased considerably by retarding the change in magnetic flux. This is done most readily by encircling the magnetic path by a low resistance conducting path. A copper sleeve over the core, shorted windings, or a stack of copper washers on the coil form all achieve similar effects. The release time is increased appreciably more than the operating time by these techniques. External time delay elements in the relay energization circuits slow response. Short circuiting the operating winding to release the relay increases release time. A low circuit current provides increased operation time.

CONSTRUCTION FEATURES

The almost complete absence of construction and dimensional standards for sensitive relays have led to a great variation in commercially available types. Unenclosed, partially enclosed, sealed, gasket sealed and hermetically sealed enclosures (see Table I for suggested definitions of these terms) are used depending on the degree of protection from contamination required. The sealed relay has both coil and contacts enclosed in an airtight cover which may be removed for adjustment. The hermetically sealed relay is permanently sealed and requires fusing or soldering but does not use a gasket. The hermetically sealed relay offers the additional advantage of maintaining internal conditions so as not to accentuate arcing problems at high altitude.

Relay terminals, reflecting the absence of standards, are available in a great variety of types. Solder pins of differing shape are commonest in miniature models. Plug in and connector terminals are also used. Solder type connections are preferred in applications where shock and vibration requirements are more important than the need for easy replacement. The arrangement and manner of insulation of relay terminals is a function of voltage ratings, where the most severe condi-

tions, usually high altitude, apply.

Sealed construction which maintains sea-level conditions within the relay and provides protection from harmful components in the atmosphere may greatly improve reliability in severe environments. However, gasses may be emitted within the sealed structure, particularly at high temperatures, which may deposit out as thin-non-conducting films on the contact surfaces. These films are a major source of unreliability in sensitive relays where contact pressure is relatively low, and in "dry-circuit" applications operating at voltage and current levels too low to puncture and burn away insulating films. While wiping action is helpful in overcoming this problem, it is important to specify and suitably process construction materials which will not gas in the relay temperature range (including internal temperature rise). Iron Fireman Manufacturing Co. employs a double-sealed construction in which the contacts are isolated from the contaminating outgassing of organic materials of the coils (see Fig 8), by sealing the contacts in an hermetically sealed capsule within the outer sealed shell. The soldering process used in sealing eliminates use of contaminating flux.

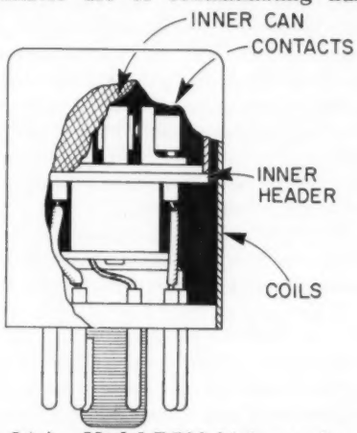


Fig 8(a)—Model R500 high speed sensitive relay showing the contacts enclosed in a separate hermatically sealed compartment within the outer case, which is also hermetically sealed. This double sealing in inert gas eliminates any possibility of contact contamination from the outgassing from the coils.

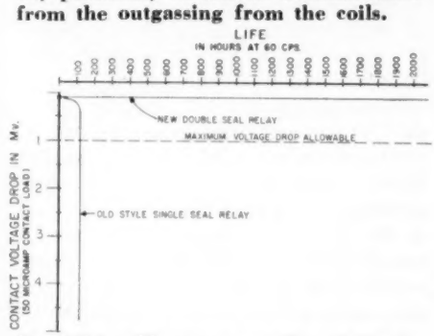

LIFE
IN HOURS AT 60 CPS
NEW DOUBLE SEAL RELAY
MAXIMUM VOLTAGE DROP ALLOWABLE
OLD STYLE SINGLE SEAL RELAY
CONTACT VOLTAGE DROP IN MV.
(50 MICROAMP CONTACT LOAD)

Fig 8(b)—These curves taken from the actual low level tests on each relay show the improvement in life of the double seal relay over the conventional type.

ANALOG TO DIGITAL CONVERTERS

(GRAY, BINARY CODED DECIMAL)

1:1000; 1:3600; 1:216,000

For Missile and Airborne Applications

Speed and life . . . *with bi-directional read-out*

8,000 bits/min for 500 hours plus 2,400 bits/min for 1000 hours
20,000 bits/min for 300 hours plus 2,000 bits/min for 1700 hours

- Direct read-out at 20ma — 40V dc
- No brush lifting — no diodes — no networks
- Each code transfer point is unambiguously defined by a 9° least significant bit
- Passes MIL-E-5272B up to 100°C
- Ascending code—clockwise on shaft
- Synchro type mounting with pilots
- EVALUATION UNITS AVAILABLE WITHIN 30 DAYS

FOR SPECIFICATIONS SHOWN HERE, ORDER BY PART NUMBER

IDL Part Number	500206	500216	500217
Total number of bits	1000	3600 (0.1°)	216,000 (0.1′)
Accuracy (Resolution)	1 bit in 1000	1 bit in 3600	1 bit in 216,000
Max/Min Torque (in. oz.)	1.5/.3	1.5/.3	3.5/.3
Bits per shaft revolution	40	40	40
Weight (incl. cables)	4.7 oz.	4.8 oz.	8 oz.
Case Length	2⅜ in.	2⅜ in.	2⅜ in.
Mounting Pilot	1.754" dia.	1.754" dia.	2.156" dia.

Other models available.

For prices and complete specifications write

INSTRUMENT DEVELOPMENT LABORATORIES, INC.
Subsidiary of Royal McBee Corporation
66 MECHANIC ST., ATTLEBORO, MASSACHUSETTS, U.S.A.

CIRCLE 50 ON INQUIRY CARD

Here are 3 top jobs for a top company in the field of precision materials testing

About INSTRON . . . and opportunity

Instron is an acknowledged front-runner in the field of instrumentation for precision materials testing. We choose our engineers with care —and when we've found the right man, we do everything in our power to make him feel he has a really worthwhile and creative job. If you're looking for a challenging and rewarding opportunity,

Electronic Development Engineer

To design electronic and electromechanical laboratory instruments. Should be experienced in general electronics, servo mechanisms, analog and digital systems, transducers and relay circuitry. Opportunity to introduce new concepts of instrumentation to the field of materials testing. Requires 6-8 years development experience.

Mechanical Design Engineer

To design mechanical, electromechanical and hydraulic mechanisms for the physical studies of materials. Experience required in designing all types of ingenious mechanisms, precision gear trains, and structures, plus background of shop practice and manufacturing processes. Opportunity to participate in a variety of interesting projects concerned with equipment for materials research.

High Temperature Engineer

Experienced in mechanical design and thermodynamics. To develop very high temperature equipment for metallurgical and ceramic research. Involves furnace and vacuum capsule design. Opportunity to develop reputation through field work with other experts in this new science.

Send Your Resume Today To D. R. Erb

INSTRON
ENGINEERING CORPORATION
2500 Washington St., Canton, Mass.

CIRCLE 51 ON INQUIRY CARD

ENGINEERS/EE/ME/AE

FOCAL POINT FOR CAREERS IN SYSTEMS ENGINEERING

General Electric's New Defense Systems Dept.

From many diverse disciplines in engineering and the sciences, capable men are coming together to form the nucleus of the new Defense Systems Department—*an organization devoted exclusively to conceiving, integrating and managing prime defense programs, such as:*

ATLAS
DYNA-SOAR
SENTRY
and other highly classified systems which cannot be listed here.

Whether you are a systems engineer now or not, the inauguration of this new department presents a rare opportunity for bringing *your own career* into sharp focus in systems engineering.

Immediate assignments in

SYSTEMS PROGRAM MANAGEMENT
WEAPONS ANALYSIS
WEAPONS SYSTEMS INTEGRATION
ELECTRONICS • DYNAMICS
COMPUTER LOGICAL DESIGN
PRELIMINARY DESIGN
APPLIED MATHEMATICS
ADVANCED SYSTEMS DEVELOPMENT
SYSTEMS EVALUATION
THEORETICAL AERODYNAMICS

Please direct your inquiry in strictest confidence to Mr. E. A. Smith, Dept. 4-J.

DSD

DEFENSE SYSTEMS DEPARTMENT
GENERAL ELECTRIC
300 South Geddes Street
Syracuse, New York

CIRCLE 52 ON INQUIRY CARD

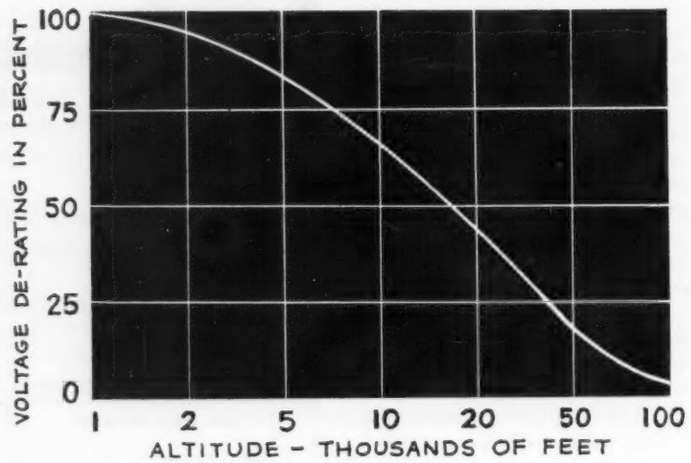


Fig 9—Voltage de-rating with altitude

ENVIRONMENTAL REQUIREMENTS

Components Digest 4 covered the general topic of environmental specifications, emphasizing the commonly referenced government specifications, MIL-E-5272A, MIL-E-5400B (ASG), MIL-T-5422C (ASG), and MIL-STD-20D. These specifications frequently govern environmental requirements to the extent indicated in detail specifications, and in the few pertinent military specifications such as MIL-R-5757C of July 26, 1955 for armature type relays for electronic and communications equipment, and MIL-R-25018 (USAF), an airforce specification for miniature hermetically sealed relays for airborne equipment. They apply only to a limited variety of general purpose relays having wide application. In general the military specifications are inapplicable to the more specialized sensitive relays except to provide paragraphs for reference in preparing detail specifications. The types of failures induced by the different environmental tests as described in Components Digest 4 apply in a general manner to sensitive relays. Nevertheless certain relay problems require further consideration.

The principal sources of relay failure derive from inadequate information regarding behavior under different environmental conditions. Vibration is probably the most serious problem, particularly in airborne and missile applications requiring tests to 2000 cps Complex wave vibration as well as acoustic noise testing have further emphasized vibration problems. Some believe that complex wave vibration testing is superfluous as long as special care is given to all resonant points in the test spectrum. Vibration difficulties may be minimized by use of a balanced armature construction (see Fig. 2), by operating the relay where possible at a considerable differential between pull-in and drop out currents, and sometimes by optimum orientation of the relay in use. Rotary vibration may occasionally introduce unanticipated difficulties. Sensitive relays with low control power are particularly subject to vibration failure.

Shock is similar to vibration in its effects on relay performance, but the increased impact severity associated with shock may cause structural damage, as well as temporary motion of the contacts. High temperatures speed up the build up of contamination due to gassing of impurities and unsuitable materials. The d-c resistance of the coil increases about 20% for a temperature rise of 50C (temperature coefficient of copper) resulting in a change in operating voltage. Low temperatures reduce coil resistance correspondingly. Temperature variations similarly effect spring materials, contact settings, and generally introduce mechanical distortion of the members.

Pivot points are particularly sensitive to temperature extremes where variations in pivot friction due to differential expansion coefficients can shift operating points. Lubricants are out of the question where they introduce low temperature sluggishness. These problems are all the more severe in sensitive relays where forces are light.

New environmental problems include non-operative storage over long periods, such as in stored missiles. For unsealed relays, these storage condi-

tions are equivalent to long drawn-out environmental tests, with day-by-day variations in temperature and humidity. For sealed relays, contact contamination during long periods of non-use may turn out to be serious. Frequently it is of vital importance that immediate perfect response be achieved after a storage period of many years. In some applications routine testing at intervals is part of a continuing preventative maintenance program.

Humidity may stimulate electrolytic corrosion, particularly at higher temperatures. However suitable sealing and choice of materials and protective finishes are usually adequate to cope with this problem.

Altitude affects relay performance by increasing the susceptibility to arcing both at contact points and at the header terminals, and by reducing convection cooling from the relay surfaces. Contact ratings of hermetically sealed relays are of course not affected. Fig. 9 shows the voltage derating of an unsealed relay as a function of altitude.

Because of contamination by internal materials which emit gases (particularly at high temperatures) which adversely affect contact life, sealing the relay is not accepted as the final answer to environmental problems. Estimates of contact life reduction as a consequence of sealing have ranged from factors of 2 to 10.

The contact cleanliness required in dry-circuit application suggests the use of sealed relays and a strong contact wiping action to remove contaminating films. Such developments are an important area of current investigation.

As with all devices, reliability is best served by conservative application, with generous safety factors for operating points, contact ratings and environmental resistance. Relay manufacturers suggest that improper application is the principal source of relay failure. We trust that general agreement on definitions and test methods currently under study by NARM Committees will eliminate much misunderstanding and misapplication.

RELAY CONTACTS

The most critical elements in relay performance are the contacts. They must be designed to last for the life of the unit under rated conditions of load, coil excitation and environment. Choice of contact material is a function of the required load and life, the available contact pressure, and the associated environment. Size of the contact must be adequate to absorb the heat generated by opening and closing, and to survive the erosion occuring in normal use. Fig. 10 shows a typical variation in contact life of a Sigma relay under various loads. Silver contacts are the most widely used general purpose contacts in sensitive relays and gold, in dry-circuits, although other materials are common.

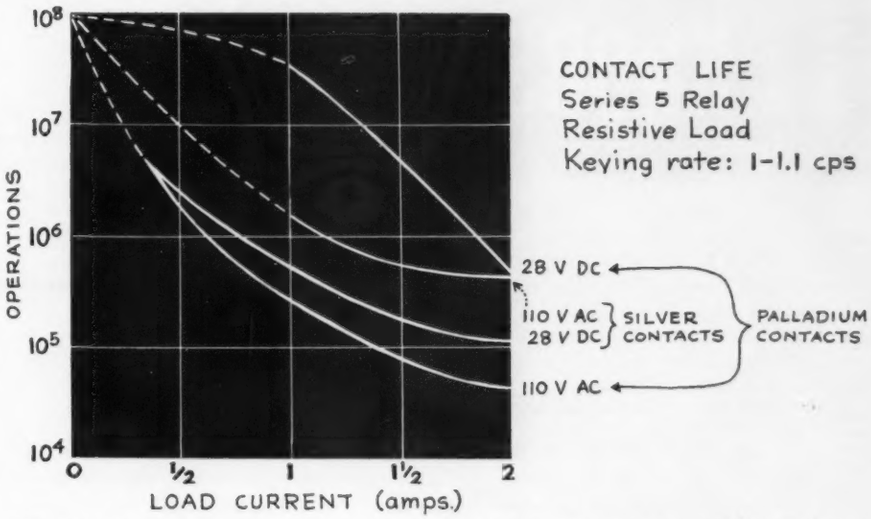


Fig 10—Typical life vs. load characteristics for several operating conditions for a Sigma relay

Design of the magnetic circuit and the contact supporting springs should eliminate or minimize bounce, and provide for "clean" make and break action. Some wiping motion in engagement of contacts is extremely helpful in maintaining a clean oxide-free surface having low contact resistance and resulting in good reliability.

Contact arcing occurring upon opening of an inductive circuit results in melting of metal, pitting, and perhaps ultimately welding of the contacts, as well as the generation of transients and radio frequency interference in adjacent or associated circuitry. Peak surge voltages during opening of an inductive circuit may puncture insulation. In general high speed opening of contacts minimizes arcing problems. Energizing tungsten filament lamps may cause inrush currents of 10 times rated value, which may seriously reduce contact life.

The commonest and most satisfactory way to increase contact life by factors up to 100 in inductive circuits is by means of arc suppression. Arc suppression circuits connected directly across the contacts can minimize transients, avoiding peak voltages, and cut contact erosion sharply. The typical arc suppression circuit shown in Fig. 10 consists of a series resistor and capacitor. The capacitor acts to reduce the voltage at the moment of contact break. The resistor limits the surge current due to the capacitor discharge at the instant of contact closure. Adjustments of R and C are best carried on experimentally by observing the voltage pattern across the contacts during a cycle excitation.

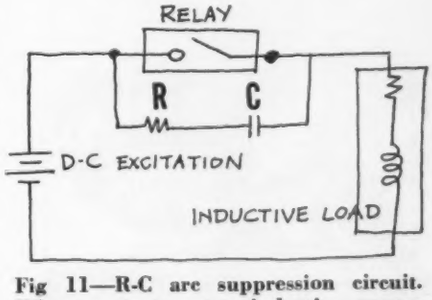


Fig 11—R-C arc suppression circuit. When contact opens, inductive energy builds up in capacitor. On closing the contact, relay inrush current is limited by the resistor.

Engineering Note E-401 of the Servomechanisms Laboratory, MIT suggests an R-C time constant equal to the time constant of the inductive load. The value of resistance should be small, and the value of capacitance large, consistant with the time constant equality requirement. However, the values of R and C are not critical. During experimental adjustment of an arc suppression circuit the engineer may be prematurely satisfied when visible arcing has vanished. He may be unaware of the extremely high momentary currents which may be caused by condenser discharge upon closing of the contacts. Such heavy discharge current can cause contact welding, which the series resistor is intended to limit.

NATIONAL
MIL-SPEC KNOBS

In stock! For immediate delivery! And produced by National!... a complete line of standard plastic control knobs made in conformance with MS-91528. There are four basic types: round, pointer, spinner (each with or without skirts) and dial skirted round . . . available in three different shaft sizes. Finishes are gloss, matte, or to your color specifications . . . in all Mil-Spec sizes.

Knobs: Made of plastic, type III, class H2, per Specification L-P-349. Set Screws: Cadmium plated, class 3, type II, per Specification QQ-P-416. Inserts: Brass, composition 4, hard, per Specification QQ-B-613. For price quotations and complete information write:

Since 1914
National
Company, Inc. Malden 48, Mass.

CIRCLE 6 ON INQUIRY CARD

SENSITIVE RELAYS, Cont.

Rectifiers placed back to back in non-conducting opposition provide a method for limiting peak voltages. The high instantaneous overload capacity of Selenium rectifiers makes them particularly useful for this type application. Fig. 12 shows additional arc suppression circuits and explain their operation.

Arc suppression circuits applied even in moderate to low power inductive circuits frequently increase contact life by a factor of a *hundred* or more. The R-C suppression circuit is most suitable where contact current is less than about an ampere. Arc suppression circuits do slow down the response of the external circuitry by continuing the current flow briefly upon opening of the contacts.

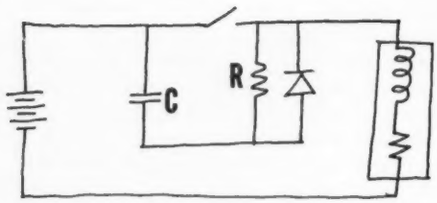


Fig 12(a)—Arc suppression circuit using a rectifier. The low forward resistance of the rectifier permits quick capacitor charge during opening of the relay. Capacitor discharge on closing of the contact is limited by R.

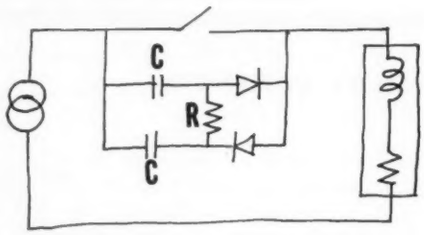


Fig 12(b)—A-C version of the circuit of Fig 12(a).

DRY CIRCUITS

There is no formal definition of a "dry" circuit. Generally, it means a low level circuit exhibiting special contact phenomena as a result of the reduced voltage, current, and power involved. Dry-circuit operation is frequently found in analog computers where relays are used for switching to establish signal flow paths, and where the signals may at times have values close to zero. They similarly occur in vacuum-tube grid circuits, and in many control operations in missiles. Unfortunately the problems in reliable low-level switching applications are more severe than in more conventional applications.

The dry circuit switching problems may be explained in terms of the contact surfaces. Regardless of the finish on the contact, at the microscopic level considerable roughness exists, which together with the presence of microscopic dust particles leads to a preliminary contact at a number of discreet points. The resistance associated with this initial contact is high. If the current flow is sufficient to cause a softening at the contact points increasing the effective contact area, an extremely rapid drop in resistance occurs, and an effective contact is established. In such a contact electrons flow smoothly from one surface to the other as a result of

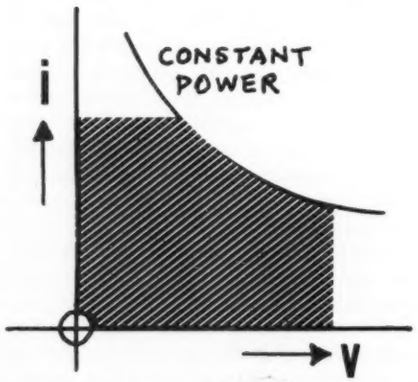


Fig 13—A region of dry circuit operation, bounded by current, voltage and power limits. (Suggested by Mr. Holcomb of Sigma Instruments Corp.)

the continuity established by slight welding. Where voltage, current and power of the controlled circuitry are inadequate to create this welding, the contact resistance remains high, and may be regarded as *dry*, see Fig. 13.

Additional factors relating to the contact surface are involved. Any oxidation of the contact surfaces or condensation of gaseous substances, released from the internal construction materials of the relay, that result in non-conducting films retard the establishment of a good electrical contact in low level circuits. Where voltage is sufficiently high to break through the films and current is adequate to burn

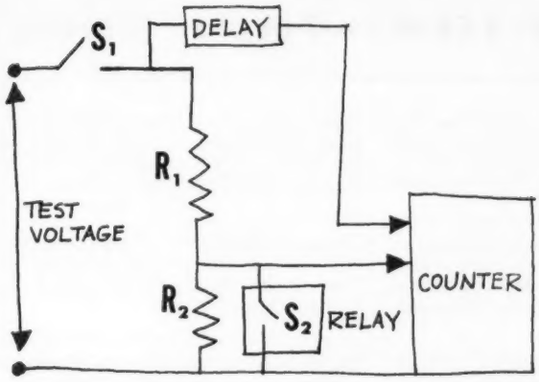


Fig 14—Miss-testing circuit. S_1 and S_2 are synchronized. R_1 and R_2 are adjusted for suitable dry-circuit ratings of the relay under test. The delayed signal sets the counter to record a "miss" if voltage appears across S_2, indicating a faulty contact closing.

away the non-conducting elements the problem may be trivial. In dry circuit applications, however, this is not the case.

Relays designed for dry circuits generally employ noble metal contact materials whose non-tarnishing surface qualities minimize contact resistance. Wiping action upon energization of the contacts tends to keep surfaces free of contaminants. Dust free enclosures and maximum contact pressures compatible with required sensitivity lead to improved initial contact. In hermetically sealed units, the greatest care is taken to minimize the use of materials that emit gases during normal use, particularly at elevated temperatures. Materials such as Bakelite are completely out of the question. Fumes from impregnated relay coils and sealing compounds are principal offenders.

Bifurcated contacts, consisting of two essentially separate contacts in parallel provide greatly increased dry circuit reliability. If the cycles between failures average 100,000 for a single contact, then the figure should be (theoretically) 1,000,000 squared, or 10^{10} for both contacts operating in parallel. While this may seem to be practically perfect reliability, performance of this type is essential for the successful operation of equipment containing hundreds of thousands of components.

A factor in many dry circuit applications is the problem of insulation resistance. During switching of the grid circuits of extremely sensitive d-c amplifiers, circuit resistances may be many megohms, even hundreds of megohms. In such instances the required insulation resistance between relay contacts and the frame may be thousands of megohms, a figure sometimes difficult to attain, especially when humidity causes low resistance between header terminals and the case. Design of contact supports and the header using glass or similar materials as insulators can lead to a satisfactorily high insulation resistance.

Dry circuit reliability is principally a matter of assuring good electrical contact each and every time during operation. Reliability testing is a matter of measuring the number of misses or some equivalent figure in a long sequence of operation. Fig. 14 shows a schematic diagram of a miss-testing circuit. An ingenious variety of such circuits are employed. Depending upon the philosophy of the manufacturer, or on the requirements of the user, a-c or d-c may be applied to the contacts. There is no general agreement on which constitutes a better test, although contact phenomena certainly differ in a-c and d-c circuits. One manufacturer uses a reversing d-c switching polarity with each cycle. Although the borderline contact voltage for dry circuit behavior is definitely a function of the contact materials (300 mv for silver, for example) extensive use of noble metals for dry circuit relays has led many manufacturers to use an arbitrary test voltage for dry-circuit testing purposes. In special instances, however, it would be more suitable to match actual operating conditions as closely as possible. Initial failures are weeded out by a preliminary production test consisting of some thousands of cycles of operation to catch failures which may result from construction faults or internal contamination.

Sigma Instruments, Inc. employs a production test of dry circuit relays based upon 5000 operations without failure in a circuit subjected to a test signal of 10 microamperes at 10 millivolts (1000 ohms maximum resistance). Open circuit voltage is a maximum of 20 millivolts and short circuit current 20 microamperes maximum. This test is applied only to hermetically-sealed dry-circuit relays that have never been subjected to other than dry-circuit loads.

It is not feasible to put dry-circuit requirements on relays used in circuits carrying appreciable power. To do so would only lead to unsatisfactory compromises and poor overall performance.

WANTED

PROPRIETARY
Electronic or
Electromechanical
PRODUCTS

for Manufacture
Assembly or
Distribution

NATIONAL SALES PROGRAM AVAILABLE

Write to:
Electronic Assembly Co.
Five Prescott Street
Roxbury 19, Mass.

HOW TO INTERPRET THE CHARTS OF TABLE II

The charts in Table II list important characteristics of a variety of sensitive relays. The coverage is not intended to be complete but rather to be illustrative of available types, to facilitate preparation of realistic specifications.

The reader is warned to interpolate the tabulated material with caution. Many data listed represent performance limits that apply only under restricted conditions. Relays that appear to be "inferior" may have decided advantages in price or reliability. The absence of uniform standards means that comparison of listed data is inapplicable, because of different test conditions or definitions. For example, a shock specification of 30 g's may mean without damage, or without affecting the contacts. Clearly the latter is a more severe requirement.

No assumptions should be made about omitted data without checking with the manufacturer. Through oversight important manufacturers and relays may not have been covered. The continuing nature of the Components Digest series allows us to present supplementary sheets as they are compiled, to keep our coverage up to date.

Table I – DEFINITIONS OF RELAY TERMS – Partial Listing.

Armature Relay—*An armature relay is a relay operated by an electromagnet which, when energized, causes an armature to be attracted to a fixed pole (or poles).*

Bridging—*Bridging is a term used to describe a contact transfer in which the movable contact touches the normally open contact before leaving the normally closed contact during the transfer action, thus never completely opening the circuit of the movable contact.*

Chatter—*Chatter is a sustained rapid opening and closing of contacts caused by variations in the coil current, mechanical vibration and shock or other causes.*

Contact Bounce—*Contact bounce is the uncontrolled making and breaking of contact when relay contacts are moved to the closed position. (See figures B and C).*

Contact Nomenclature—*Each of the movable contacts of a relay constitutes a pole of the relay.*

A combination of a stationary contact and a movable contact which are engaged when the coil is unenergized is referred to as back, break, form B or normally closed contacts and is abbreviated NC. A combination of a stationary contact and a movable contact which are engaged when the coil is energized is referred to as front, make, form A or normally open contacts and is abbreviated NO.

A combination of two stationary contacts and a movable contact which engages one of them when the coil is energized and engages the other when the coil is unenergized is called transfer, form C or double-throw contacts and is abbreviated DT.

Contrasted with double-throw contacts, NO and NC contacts are called single-throw contacts, abbreviated ST.

A combination in which a movable contact simultaneously makes and simultaneously breaks connection between two stationary contacts is called double-break contacts and is abbreviated DB. For normally open contacts, this combination may be called double-make contacts.

Relay contact notations are given in the following order:

1. *Poles*
2. *Throws*
3. *Normal Position*
4. *DB, if double-break or double-make contacts.*

Examples: SPST NO DB designates single throw, normally open, double-break contacts.

All contacts are single break except when noted as double break (DB).

Relays having several sets of differently functioning contacts will have the contact forms listed in alphabetical order of their letter symbols as given in Figure A.

Example: 1A2B refers to SPST NO contacts and DPST NC contacts.

For a relay on which the moving contact engages more than two stationary contacts during its cycle of operation, the contact arrangement is described as MPNT, where M is the number of poles and N is the number of throws, e.g., 8P2OT.

Delay Relay—*A delay relay is a relay that is intentionally designed for a time delay between the energizing or deenergizing instant and the time that the relay contacts open or close.*

Differential Relay—*A differential relay is a relay having multiple windings which functions when the voltage, current or power difference between the windings reaches a predetermined value.*

Drop-Out Values—*The drop-out current, voltage or power is the maximum value for which the contacts of a previously energized relay will always assume their unenergized positions. (See Figure D).*

Enclosed Relay—*An enclosed relay is a relay which has both coil and contacts protected from the surrounding medium by a cover that is not airtight.*

Fast-Operate Relay—*A fast-operate relay is a high-speed relay specifically designed for short operate time but not short release time.*

Fast-Operate, Fast-Release Relay — *A fast-operate, fast-release relay is a high-speed relay designed for both short operate time and short release time.*

Fast-Operate, Slow-Release Relay — *A fast-operate, slow-release relay is a relay specifically designed for short operate time and long release time.*

Fast-Release Relay—*A fast-release relay is a high-speed relay specifically designed for short release time but not short operate time.*

Gasket-Sealed Relay—*A gasket-sealed relay is an airtight relay, the sealing of which involves the use of a gasket which is not bonded to the other sealing material.*

General-Purpose Relay—*A general-purpose relay is a readily available relay which has design, construction, operational characteristics, and ratings such that it is adaptable to a wide variety of uses.*

Header—*A header is the part of a hermetically sealed relay through which the electrical terminals pass.*

Hermetically Sealed Relay—*A hermetically sealed relay is an airtight relay the sealing of which involves fusing or soldering but does not use a gasket.*

High-Speed Relay—*A high-speed relay is a relay specifically designed for short operate time, release time, or both.*

Hold Values—*The hold current, voltage or power is the minimum value for which the contacts of a previously energized relay will always maintain their energized positions (See Figure D).*

Instrument Relay—*An instrument relay is a relay, the operation of which depends upon principles employed in electrical measuring instruments such as the electrodynamometer, iron-vane and D'Arsonval.*

Make-Before-Break Contacts — *Make-before-break contacts are double-throw contacts so arranged that the moving contact establishes a new circuit before disrupting the old one (See Figure AD).*

Marginal Relay—*A marginal relay is a relay which functions in response to predetermined changes in the value of coil current or voltage.*

Multiple-Break Contacts — *Multiple-break contacts are contacts so arranged that, when they open, the circuit is interrupted in two or more places (See Figure A, U-Z).*

Non-Bridging—*Non-bridging is a term used to describe a contact transfer in which the movable contact leaves one contact before touching the next.*

Non-Inductive Winding—*A non-inductive winding is a type of winding in which the magnetic fields produced by two parts of the winding cancel each other and provide a non-inductive resistance.*

Non-Operate Values — *The non-operate voltage, current or power is the maximum value for which the contacts of a previously deenergized relay will always maintain their deenergized positions (See Figure D).*

Operate Time—*If a relay has only normally closed contacts, its operate time is the longest time interval given by definition (a) below. If a relay has normally open contacts (regardless of whether or not it has normally closed contacts) its operate time is the longest time interval given by definition (b).*

(a) Operate Time for Normally Closed Contacts—Operate time for normally closed contacts is the total elapsed time from the instant the coil is energized until the contacts have opened; i. e., the contact current is zero (See Figure B).

(b) Operate Time for Normally Open Contacts—Operate time for normally open contacts is the total elapsed time from the instant the coil is energized until the contacts are closed and all contact bounce has ceased (See Figure B).

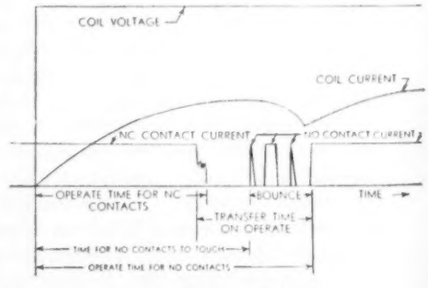


Figure B

As suggested by the National Association of Relay Mfgrs.

Partially Enclosed Relay—*A partially enclosed relay is a relay which has either contacts or coil (but not both) protected from the surrounding medium by a cover that is not airtight.*

Partially Sealed Relay—*A partially sealed relay is a relay which has either contacts or coil (but not both) sealed.*

Pick-Up Values—*The pick-up voltage, current or power is the minimum value for which the contacts of a previously deenergized relay will always assume their energized positions (See Figure D).*

Pile-Up—*A pile-up is a set of contact arms, assemblies or springs placed one on top of the other with insulation between them.*

Plunger Relay—*A plunger relay is a relay operated by energizing an electro-magnetic coil which in turn operates a movable core or plunger by solenoid action.*

Polarized Relay—*A polarized relay is a relay the operation of which is dependent upon the polarity of the energizing current.*

Relay—*A relay is an electromechanical device which is operated by variation in the conditions of one electric circuit to affect the operation of other devices in the same or other electric circuits by either opening contacts or closing contacts or both.*

Release Factor—*The release factor is the ratio, expressed in percent, of drop-out current to rated current or the analogous voltage ratio.*

Release Time—*If a relay has only normally open contacts, its release time is the longest time interval given by definition (a) below. If a relay has normally closed contacts (regardless of whether or not it has normally open contacts) its operate time is the longest time interval given by definition (b).*

(a) Release Time for Normally Open Contacts—Release time for normally open contacts is the total elapsed time from the instant the coil current starts to drop from its rated value until the contacts have opened; i. e., the contact current is zero (See Figure C).

(b) Release Time for Normally Closed Contacts—Release time for normally closed contacts is the total elapsed time from the instant the coil current starts to drop from its rated value until the contacts are closed and all contact bounce has ceased (See Figure C).

Special-Purpose Relay—*A special-purpose relay is a relay which has an application that requires special features which are not characteristic of the conventional general-purpose or definite-purpose relay.*

Telephone-Type Relay—*Sometimes used for an armature relay with an end-mounted coil and spring pile-up contacts mounted parallel to the long axis of the relay coil.*

Transfer Time—*Transfer time is the total elapsed time between the breaking of one set of contacts and the making of another set of contacts.*

(a) Transfer Time on Operate—The transfer time on operate is the total elapsed time from the instant the normally closed contacts start to open until the normally open contacts are closed and all contact bounce has ceased (See Figure B).

(b) Transfer Time on Release—The transfer time on release is the total elapsed time from the instant the normally open contacts start to open until the normally closed contacts are closed and all contact bounce has ceased (See Figure C).

Unenclosed Relay—*An unenclosed relay is a relay which does not have its contacts or coil protected from the surrounding medium by a cover.*

Wiping Contacts—*Wiping contacts are contacts designed to have some relative motion during the interval from the instant of touching until completion of the closing motion.*

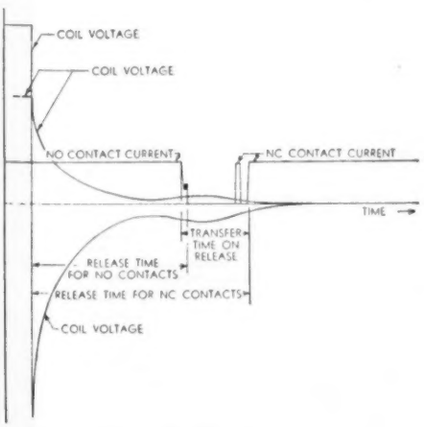


Figure C

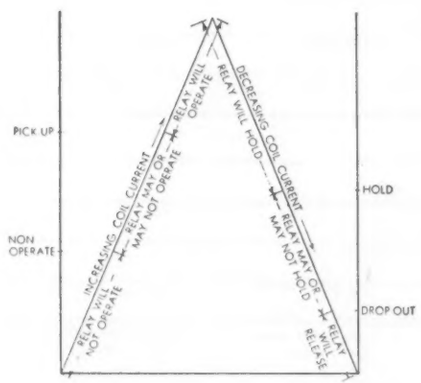


Figure D

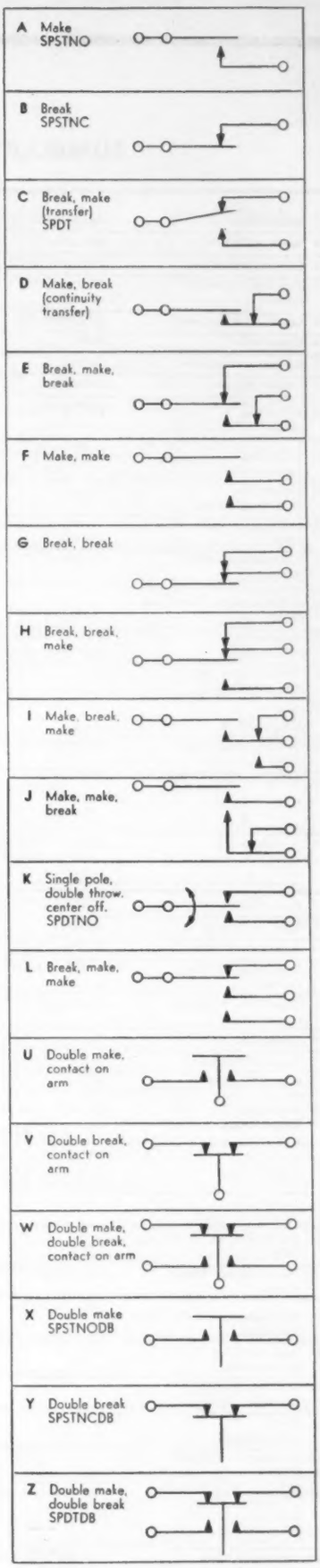

A Make SPSTNO
B Break SPSTNC
C Break, make (transfer) SPDT
D Make, break (continuity transfer)
E Break, make, break
F Make, make
G Break, break
H Break, break, make
I Make, break, make
J Make, make, break
K Single pole, double throw, center off. SPDTNO
L Break, make, make
U Double make, contact on arm
V Double break, contact on arm
W Double make, double break, contact on arm
X Double make SPSTNODB
Y Double break SPSTNCDB
Z Double make, double break SPDTDB

Figure A

TABLE II

SUMMARY OF SENSITIVE RELAY CHARACTERISTICS

1	Manufacturer	Automatic Electric	Allied Control Co.	Allied Control Co.	Allied Control Co.	Babcock Relays, Inc.
2	Model or Type No.	Ser. PLD	SWS	RSH	T165	Ser. BR-1, BR-2
3	General Description	Polarized, 2 or 3 pos.	Hi-Sens., d-c	d-c actuated	Polarized	Miniature tube size
4	Principal Dimensions (Inches)	4 5/8 x 3 3/16 x 1 7/8 unenclosed	1 19/32 x 1 7/16 x 1 1/16	1 19/32 x 0.843 dia.	3 5/32 x 1 35/64 x 1 7/64	1.610 x 0.745 dia.
5	Construction Enclosure	Dust Cover	Hermetic Seal	Dust Cover	Hermetic Seal	Hermetic Seal
6	Connections	Studs	Solder, Plug In	Solder, Plug In	Solder	Solder, Plug In
7	Contact Arrangements	Various	SPDT, DPDT	SPDT, DPDT	SPDT, 3-position	
8	Contact Material	Palladium	Silver	Standard or Silver	Per requirements	
9	A-C Rating (Amps, Volts)	135[W], 3[a] Non-inductive	1[a], 115[V] Non-inductive	2[a], 110[V] Non-inductive	Per requirements	
10	D-C Rating (Amps, Volts)	135[W], 3[a] Non-inductive	1[a], 24[V] Non-inductive	2[a], 24[V] Non-inductive	Per requirements	2[a], 28[V] Non-inductive
11	Contact Life (Millions of cycles)		Per requirements	Per requirements	Per requirements	1/10, 100 at low-level
12	Coil Power (Min. to actuate) (MW)	55-100, depending on contacts	3	20/pole	0.05	30
13	Coil Resistance Range (Ohms)	15-5000	0.32 to 13,800	12 to 28,500	2.2 to 9050	
14	Coil Dissipation, Temp. rise (Watts, °C)		4.25[W], 85 °C			
15	Response Time (Milliseconds)	0.003--.010 (Operate) 0.020--.050 (Release)			200 (Operate)	10 max
16	Vibration (g's, cps, dble ampl--inches)			10g to 500 cps	Adjust for applic.	0.06" da to 55 cps
17	Shock (g's, millisec)			50g	Adjust for applic.	25g's, 11 msec
18	Ambient Temp. Range (°C)	Industrial Ambients	-55 to +85	-65 to +125	-55 to +85	to +125
19	Special Features		Sensitivities to 50 mw for greater current, more rugged	Passes many MIL requirements	Variety of design, dry-circuit available	Balanced armature, adapt. to dry-circuit close differential, MIL-R-5757B
20	Application Notes	Low level instrument circuits. Available to meet severe environments.	General purpose	Available also for dry-circuit	General application	Airborne, carrier telephone
1	Manufacturer	Elgin Nat'l. Watch Co.	Gen'l. Automatic Corp.	Gen'l. Automatic Corp.	Gen'l. Automatic Corp.	Iron Fireman
2	Model or Type No.	Ser. SV	160	Ser. 200	Type 104	Ser. 400
3	General Description	Hi-Sens., d-c	Transistorized			Dual coil, miniature
4	Principal Dimensions (Inches)	1 9/16 x 2 5/8 x 2 1/16	3 1/2 x 2 x 1 1/2	1 1/4 x 2 1/4 x 1 1/8	3 1/4 x 1 1/4 dia.	1 25/32 x 0.970 x 0.970
5	Construction Enclosure	Dust Cover	Dust Cover	Open	Open, Dust Cover, Hermetic Seal	Hermetic Seal
6	Connections	Solder	Plug In	Solder	Solder, Plug In	Solder, Plug In
7	Contact Arrangements	SPDT	SPDT, DPDT	SPDT, DPDT	Varied	DPDT, SPDT
8	Contact Material	Silver	Silver, Palladium, Gold		Silver, Palladium, Gold	
9	A-C Rating (Amps, Volts)	1[a], 115[V] Non-inductive 0.5[a], 115[V] Inductive	115[V], 3[a] Non-inductive	5[a] Non-inductive 3[a] Inductive	3[a], 115[V] Non-inductive 1[a], 115[V] Inductive	2[a], 115[V]
10	D-C Rating (Amps, Volts)	1[a], 26.5[V] Non-inductive 0.5[a], 26.5[V] Inductive		5[a] Non-inductive 3[a] Inductive	3[a], 29[V] Non-inductive 1[a], 29[V] Inductive	2[a], 28[V]
11	Contact Life (Millions of cycles)		25	25	25	1/10 at 85 °C
12	Coil Power (Min. to actuate) (MW)	5	1/100	2/pole	1-10	10/pole
13	Coil Resistance Range (Ohms)	.005-40,000			to 30,000	50-12,000
14	Coil Dissipation, Temp. Rise (Watts, °C)	4[W] max				
15	Response Time (Milliseconds)				5-15	30
16	Vibration (g's, cps, dble ampl--inches)					10-55 cps, 0.060" da; 55-500 cps, 10g's
17	Shock (gs, millisec)					50g's
18	Ambient Temp. Range (°C)		0 to +50	-55 to +85	-55 to +85	-65 to +125
19	Special Features	Balanced armature	External or internal bias required	Close differential, various contacts, low cost	Floating armature for low friction, thorough wiping action. Varied contact combinations	Balanced armature, dry-circuit applic.
20	Application Notes	Vacuum tube circuitry	Adaptable to dry-circuits, Silicon transistor version available	Industrial control	Close diff, adapt. to dry-circuit. Suitable for military application	Vacuum-tube circuits

TABLE II, Cont.

1	Babcock Relays, Inc.	Babcock Relays, Inc.	Babcock Relays, Inc.	Barber-Coleman	Basco, Inc.	Elgin Nat'l. Watch Co.
2	Ser. BR-3	BR-7	BR-8	AYLE	SR or SC	Ser. SO
3	Sub-miniature	Sub-miniature	Crystal can DPDT	Polar	Hi-Sensitive	d-c actuated
4	1 3/16 x 1 3/32 x 1 1/8	1.260 x 1.075 x 0.515	0.359 x 0.783 x 0.850	1.88 x 1.65 x 2.31	1 x 1 x 1.075	1 7/32 x 1 1/4 x 1 1/8
5	Open	Hermetic Seal	Hermetic Seal	Hermetic Seal	Hermetic Seal, Dry Nitrogen	Open, Dust Cover, Hermetic Seal
6	Solder	Solder, Plug In	Solder, Plug In	Solder, Plug In	Studs	Solder, Plug In
7	SPDT	DP	DPDT	SPDT, with neutral	SPST, SPDT	SPDT
8					Silver	Silver
9		Dry-circuit to 10^{a}	Dry-circuit to 2^{a}		3^{a}, 115^{v} Non-inductive	1.5^{a}, 115^{v} Non-inductive
10	2^{a}, 28^{v}			0.5^{a}, 30^{v} Non-inductive	5^{a}, 30^{v} Non-inductive 25^{a} 28^{v} Inductive	1.5^{a}, 26.5^{v} Non-inductive
11	1/10 at 85 °C	1/10 at 125 °C, 10^{a} Non-inductive; 5 at low level	1/10 at 2^{a}, 28^{v} d-c, Non-inductive, +125 °C; 5 in low-level circuits	0.2	1/10	
12	30	50	80	40×10^{-3}	9	40
13				13-8000	0.2-20,000	1000-10,000
14				2.75^{w}, 71 °C		3^{w} max
15	10	10 max	5 max	2	12	
16	0.06 da to 55 cps	30g's to 2000 cps	30g's to 2000 cps	MIL-E-5272A, non-op., Proc. I	10g to 500 cps	
17	20g's	50g's, 11 msec	50g's, 11 msec		100g, ND; 50g, op.	
18	-55 to +85	-65 to +125	-65 to +125	-55 to +71	-65 to +125	-55 to +85
19	Simple screw adjust. for spec. circuit requirements, low cost	Rotary, bal. arm.	Rotary, bal. arm., spec. adj.	Very rugged, close differential	MIL-R-5757C, adapt. to dry circuit	Balanced arm., close differential
20	Test equip., electric circuits	Aircraft, missile, shipboard	Dry-circuit, power, in severe environments	Operates directly from photocell, null detect., diff. relay	Military	
1	Iron Fireman	Iron Fireman	Kurman Electric Co.	Kurman Electric Co.	Magnetic Devices	National Co., Inc.
2	Ser. 650	Ser. 800	Ser. P	Ser. T	300-1	3000
3	Dual coil, micro-min.	Dual coil, micro-min.	Polar, magnetic latch	Sub-miniature	Polar, double coil	Ball contact
4	0.875 x 0.797 x 0.359	1.281 x 0.915 x 0.410	5 3/4 (incl. pins) x 2 11/16 x 2 3/16	1 3/4 x 0.975 x 0.975	1 13/16 x 1 7/16 x 1 7/16	1.11 x 0.625 dia.
5	Hermetic Seal	Hermetic Seal	Dust Cover	Dust Cover, Herm. Seal	Dust Cover	Hermetically sealed contacts
6	Solder, Plug In	Solder, Plug In	Plug In	Solder, Plug In	Plug In	Solder
7	DPDT latching	SPDT, DPDT	SPDT	DPDT	SPDT	SPDT (non-latch)
8	Silver, gold plate		Palladium-copper, tungsten		Palney #7, and tungsten	
9	115^{v}, 2^{a}	2^{a}, 115^{v} Non-inductive		2^{a}, 115^{v}		
10	28^{v}, 2^{a}	2^{a}, 28^{v} Inductive		2^{a}, 28^{v}	0.15^{a}, 120^{v} Non-inductive 0.06^{a}, 120^{v} Inductive	2^{a}, 150^{v}
11	1/10 at +125 °C	1/10 at +125 °C				250
12	100	25/pole	to 1/50	35 (for DPDT)	15/coil	45
13	50 to 2500	20 to 10,000	to 82,000	to 20,000	25-4000	5000 at 28^{v} d-c
14				3^{w} max		
15	5	15			1 1/4	10 max
16	10-55 cps, 0.200" da, 55-200 cps, 30g	10-55 cps, 0.200" da; 55-2000 cps, 20g's				20-55 cps, 0.2" da; 55-2000 cps, 30g
17	100g's	50g's Op., 100g's Non-op.				
18	-65 to +125	-65 to +125			-60 to +85	-55 to +93
19	Balanced armature, suitable for dry-circuits	Balanced armature, double seal const.	Extreme sensitivity			Ball-type contact, long life. Many variations
20	For high shock and vibration, med. power and low level circuits	Med. power and dry circuits, high shock and vibration	Rapid teletype writer	Meets MIL-R-5757C, Class B	Armature latches	

TABLE II, Cont. Summary of Sensitive Relay Characteristics

1	Manufacturer	North Electric	Potter & Brumfield	Potter & Brumfield	Potter & Brumfield	Sigma Instruments, Inc.
2	Model or Type No.	IR-226	Ser. LTL	Ser. PW	Ser. SS	Ser. 4
3	General Description	Miniature	d-c, telephone type	Miniature	d-c, Hi-sens.	Med. sens.
4	Principal Dimensions (Inches)	1 3/4	2 27/32 x 4 5/32 x 1 1/2	1 11/16 x 0.765 dia.	1 11/16 x 1 3/4 x 1 5/16	1 5/32 x 1 5/8 x 1 1/2 unenclosed
5	Construction Enclosure	Hermetic Seal	Dust Cover, Hermetic Seal	Hermetic Seal	Hermetic Seal	Dust Cover, Gasket Seal, Hermetic Seal
6	Connections	Solder, Plug In	Solder	Solder, Plug In	Solder	Solder, Plug In
7	Contact Arrangements	SPDT, DPDT	Varied	SPDT	SPST, SPDT	IPDT
8	Contact Material	Palladium	Palladium	Silver	Silver	Silver, Palladium, Tungsten
9	A-C Rating (Amps, Volts)		4^{a}, 115^{v} Non-inductive	2^{a}, 115^{v} Non-inductive	2^{a}, 115^{v} Non-inductive	2^{a}, 120^{v} Non-inductive
10	D-C Rating (Amps, Volts)	2^{a}, 30^{v} Non-inductive		2^{a}, 28^{v} Non-inductive	2^{a}, 28^{v} Non-inductive	2^{a}, 28^{v} Non-inductive
11	Contact Life (Millions of cycles)	1/10				0.1 (100 with negligible load)
12	Coil Power (Min. to actuate) (MW)	20/pole	15/pole	25-1500	2.5-10	20-50, 10-200 special
13	Coil Resistance Range (Ohms)	20-17,000	190,000 max	to 16,000	to 60,000	0.012 to 12,000
14	Coil Dissipation, Temp. Rise (Watts, °C)					1^{w}, 40 °C, 100 °C max. coil temperature
15	Response Time (Milliseconds)	15-20				
16	Vibration (g's, cps, dble ampl--inches)	500 cps at 10g's				10g, 10-55 cps
17	Shock (g's, millisec)	50g's				75g
18	Ambient Temp. Range (°C)	-65 to +125		-45 to +85, +125 special		-55 to +85
19	Special Features	Gold contacts for low-level switching. Rotary armature. Meets MIL-R-5757C	Delays from 0.1 to 0.4 available	Balanced armature for shock and vibration	Differential coil available	Close differential adjustment
20	Application Notes	Airborne, plate circuits		Aircraft and missile	Plate, circuits, control	Assorted adjustments to meet sensitivity and environment requirements

1	Manufacturer	Sigma Instruments, Inc.	Sigma Instruments, Inc.	Sigma Instruments, Inc.	Sigma Instruments, Inc.	Sigma Instruments, Inc.
2	Model or Type No.	Ser. 5	Ser. 32	Ser. 41	Ser. 72	Ser. 73
3	General Description	Hi-sens., d-c or rect. a-c	Miniature, polar, latching	a-c or d-c	Polar, Hi Speed	Polarized min., 3 pos.
4	Principal Dimensions (Inches)	1 5/32 x 1 5/8 x 1 1/2 unenclosed	0.9 x 0.8 x 0.4	1 5/16 x 2 1/4 x 1 1/4 unenclosed	2 5/8 x 1 7/16 dia. unenclosed	1 11/16 x 0.760 dia.
5	Construction Enclosure	Dust Cover, Gasket Seal, Hermetic Seal	Hermetic Seal	Dust Cover, Gasket Seal, Hermetic Seal	Dust Cover, Hermetic Seal	Hermetic Seal
6	Connections	Solder, Plug In	Solder Terminals	Solder, Plug In	Solder, Plug In	Solder, Plug In
7	Contact Arrangements	IPDT	DPDT latch.	SPDT	IPDT	SPDT
8	Contact Material	Silver, Palladium	Silver	Tungsten	Silver, Gold (dry-circuit)	Silver
9	A-C Rating (Amps, Volts)	3^{a}, 120^{v} Non-inductive	2^{a}, 120^{v} Non-inductive	1^{a}, 120^{v}	0.5^{a}, 120^{v} Non-inductive	1.5^{a}, 120^{v} Non-inductive
10	D-C Rating (Amps, Volts)	3^{a}, 28^{v} Non-inductive	2^{a}, 28^{v} Non-inductive	1^{a}, 120^{v}	0.5^{a}, 28^{v} Non-inductive	1.5^{a}, 28^{v} Non-inductive
11	Contact Life (Millions of cycles)	1/10	1/10	1; 1000 at negative load	500 (to 1000 in dry-circuits)	1/10 at room temperature, 1 at negative load
12	Coil Power (Min. to actuate) (MW)	1-2000	50	0.06 to 0.4 va	0.3 to 40	6-35
13	Coil Resistance Range (Ohms)	0.10-26,000	13 to 7800	0.012 to 12,000	10-12,000	1000-7000
14	Coil Dissipation, Temp. rise (Watts, °C)	2^{w}, 40 °C	1^{w}, 65 °C	1^{w}, 40 °C	1.2^{w}, 40 °C; 100 °C max coil temperature	1^{w}, 40 °C
15	Response Time (Milliseconds)			2 (min.)	0.3 to 0.6	
16	Vibration (g's, cps, dble ampl--inches)	10g, 10-55 cps	30g to 5000 cps	10g, 10-55 cps, d-c only	to 2000 cps	10g to 500 cps
17	Shock (g's, millisec)	75g	100g, no damage	100g (without damage)		100g
18	Ambient Temp. Range (°C)	-55 to +100	-65 to +125	-55 to +85		-65 to +100
19	Special Features	Close diff. adjust., dual coil	Especially compact, magnetic latching	Hi-sens. a-c relay, low cost, fast	2 or 3 positions, very little magnetic leakage	Miniature
20	Application Notes	For differential application			For high speed relaying, to 500 pulses/sec	Avail. magnetically biased and latching, guided missiles

version available

able for military applic.

It takes a TEAM
to solve timing problems

The control of time is an extremely complex science that demands a thorough knowledge of many individual technologies. For this reason, Haydon maintains a team of engineering specialists to provide the reservoir of skill, knowledge, experience, and creative ability necessary to solve industry's timing problems.

When you submit a timing problem to Haydon, it's handled by a team of specialists – *not* an individual engineer. And you can be sure the Haydon Timing Team is equipped with all the electric, electronic, mechanical and manufacturing know-how needed to analyze your requirements and develop the best possible new or modified timing unit for your specific application.

Correctly designed and efficiently manufactured, Haydon timing devices are exhaustively tested before release to a customer. The results are uniformly high quality devices that are known for fine performance, and long life. May we put our Timing Team to work for you?

A few units from the complete Haydon line are shown at the right. Send now for further information, outlining your requirements.

Haydon
AT TORRINGTON

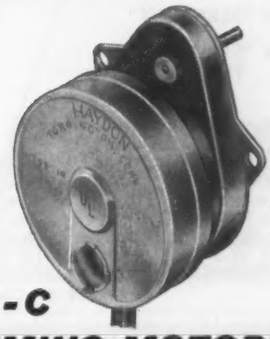
DIVISION OF
GENERAL TIME CORPORATION

2828 EAST ELM STREET
TORRINGTON, CONNECTICUT

Headquarters for Timing

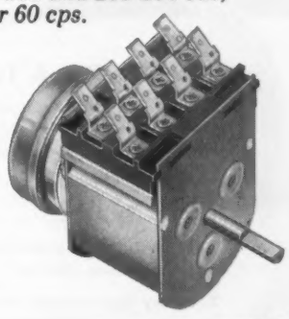
ELAPSED TIME INDICATOR ED-71

Compact, low-cost instrument for machine tools, communications equipment and other commercial applications where an accurate record of operating time is desired. Time Registered: 9,999.9 hours. Weight: 5 oz. Voltages: 120 or 240 v, 60 cps. Power Required: 2.5 watts at 120 v, 60 cps.



A-C TIMING MOTORS

A complete line of synchronous, compact timing motors, speeds from 1/60 to 60 rpm. Guaranteed torques from 6 ounce-inches to 30 ounce-inches at 1 rpm. Voltage ranges 103-132 and 206-264 vac, 50 or 60 cps.



INTERVAL TIMER

Directly controls heavy duty electrical loads. Type AD can be supplied with up to 3 SPST switches. Type AT has 1 SPST switch only. Intervals available with dial and knob: 15, 60 and 180 minutes. Intervals to meet your specific requirements can be supplied. Voltages: 120 or 240 v, 50 and 60 cps. Switch Rating: 28 amps, 250 vac non-inductive; 1 hp, 240 vac.

CIRCLE 53 ON INQUIRY CARD

"OFF THE SHELF"
Precision Components
At Low Cost

- PRECISION POTENTIOMETERS
  Single-turn Multi-turn
- SYNCHROS
- SERVO MOTORS
- SERVO MOTOR GENERATORS
- TACHOMETER GENERATORS
- GYROS
- SERVO AMPLIFIERS
- GEARS & PRECISION GEAR UNITS
- PRESSURE TRANSDUCERS
- "SERVO-KIT"
- "SERVO-SPEED TORQUE-UNIT"

Special Offerings

SAVE OVER 50% ON PRECISION SINE-COSINE POTS

T.I.C. Type RVP3 S13 Sine-Cosine Potentiometer. 20K., ±5% ORV, ±.35% Peak to Peak Conformity (built to Sperry Specs). Resolution .03% max., .12% min. 3 Watts. 360° electrical contact and functional angle. 3" diam. tapped hole mount. Shaft ¼" dia. x ⅜".

Stock # PS-155 ..... $21.50

WRITE FOR QUOTATIONS ON GANGING

SERVO MOTOR-GENERATOR

GM Labs Type 665-51-12, 400 cy. 26v. per ph. 6500 RPM no load, .35 oz. in. stall torque. Gen. output .3v. per 1000 RPM. Stainless steel housing .980" dia. x 2-5/32" long. Pinion shaft 96P 10T. x ½" long.

Stock # CM-143 . $49.50

WRITE FOR COMPLETE CATALOG

THE SERVO SYSTEMS CO
14 CARMER AVENUE BELLEVILLE 9, N. J.
PLymouth 9-2875

CIRCLE 55 ON INQUIRY CARD

push-pull CONTROLS

Compression & Tension Type

Aircraft cable is strung with spherical steel shells in a rigid or flexible housing sealed with "O" rings. 3" standard bend radius. ¾" minimum bend radius.

Three Types:

1. *Light Duty*—Compression Ult. Load 1250 lbs.; Ult. tension 960 lbs.
2. *Heavy Duty*—Compression Ult. Load 1650 lbs.; Ult. tension 960 lbs.
3. *Extra Heavy Duty*—Compression Ult. Load 3050 lbs.; Ult. tension 3900 lbs.

Positive remote controls for actuating mechanical, hydraulic or other devices. Eliminate bell cranks, pulleys and dual cables. Patented U. S. A. All world rights reserved. Send for ENGINEERING MANUAL giving detailed prints and complete specifications covering materials, finishes, capacities. Please address Dept. EMD-PP-59.

SOUTHWEST PRODUCTS CO.
1705 SO. MOUNTAIN AVE., MONROVIA, CALIFORNIA

CIRCLE 56 ON INQUIRY CARD

BUYERS' GUIDE for SENSITIVE RELAYS

Advance Relays, *2435 N. Naomi St., Burbank, Cal.*
Advanced Electronics Inc., *94 Silas Deane Hwy., Rocky Hill, Conn.*
Aemco, Inc., *10 State St., Mankato, Minn.*
Allied Control Co., Inc., *2 E. End Ave., New York 21, N. Y.*
American Instrument Co., *8030-8050 Georgia Ave., Silver Spring, Md.*
Assembly Products Inc., *Wilson Mills Rd., Chesterland, Ohio.*
Automatic Electric Sales Corp, *1033 W. Van Buren St., Chicago, Ill.*
Automatic Switch Co., *Florham Park, N. J.*

Babcock Relays, Inc., *1640 Monrovia Ave., Costa Mesa, Cal.*
Barber-Colman Co., *1300 Rock St., Rockford, Ill.*
Baso, Inc., *730 N. Jackson St., Box 461, Milwaukee 1, Wisc.*
Bunnell & Co., J. H., *81 Prospect St., Brooklyn 1, N. Y.*

Central Scientific Co., *1700 Irving Park Blvd, Chicago 13, Ill.*
Clare & Co., C. P., *3101 Pratt Blvd., Chicago 45, Ill.*
Comar Electric Co., *3349 W. Addison St, Chicago 18, Ill.*
Cook Electric Co., *2700 Southport Ave., Chicago 14, Ill.*
Couch Ordnance, Inc., *3 Arlington St., N. Quincy 71, Mass.*

Dynapar Corp., *5150 Church St., Skokie, Ill.*

Edison, Inc., Thomas A., *51 Lakeside Ave., West Orange, N. J.*

Five Star Co., The, *10 W. Main St., Plantsville, Conn.*

General Automatic Corp., *12 Carlton Ave., Montain View, N. J.*
General Electric Co., Specialty Control Dept., *Waynesboro, Va.*
Guardian Electric Mfg. Co., *1621 W. Walnut St., Chicago 12, Ill.*

Hamlin, Inc., *1316 Sherman Ave., Evanston, Ill.*
Hi-Spec Electronics Corp., *7328 Ethel Ave., N. Hollywood, Cal.*

Intra Corp., *11 University Rd., Cambridge 38, Mass.*
Iron Fireman, *2838 S. E. 9 Ave., Portland 2, Oregon.*

Kellogg Switchboard & Supply Co., *6650 S. Cicero Ave., Chicago 38, Ill.*
Kurman Electric Co., *191 Newel St., Brooklyn, N. Y.*

Larson Instrument Co., *24 Orchard St., Tarrytown, N. Y.*

Magnadyne Corp., *Box 607, 84 South Water St., Port Chester, N. Y.*
Magnecraft Electric Co., *3352 W. Grand Ave., Chicago 51, Ill.*
Magnetic Devices, Inc., *712 E. Street, Frederick, Md.*
Marion Electrical Instrument Co., *Grenier Field, Manchester, N. H.*
Mullenbach, *Box 58436, 2100 E. 27 St., Los Angeles 58, Cal.*

National Company, Inc., *61 Sherman St., Malden, Mass.*
North Electric Co., *553 S. Market St., Galion, Ohio*

Phaostron Co., *151 Pasadena Ave., S. Pasadena, Cal.*
Potter & Brumfield, Inc., *Princeton, Ind.*
Precision Thermometer & Instr. Co, *1434 Brandywine St., Phil., Pa.*
Price Electric Corp., *1500 Church St., Frederick, Md.*

Revere Corp. of America, *Wallingford, Conn.*

Sigma Instruments, Inc., *170 Pearl St., S. Braintree 85, Mass.*
Simpson Electric Co., *5200-18 W. Kinzie St., Chicago 44, Ill.*
Stevens-Arnold, Inc., *7 Elkins St., S. Boston 27, Mass.*
Stromberg-Carlson Co., *100 Carlson Rd., Rochester 3, N. Y.*
Struthers-Dunn, Inc., *Lambs Rd., Pitman, N. J.*

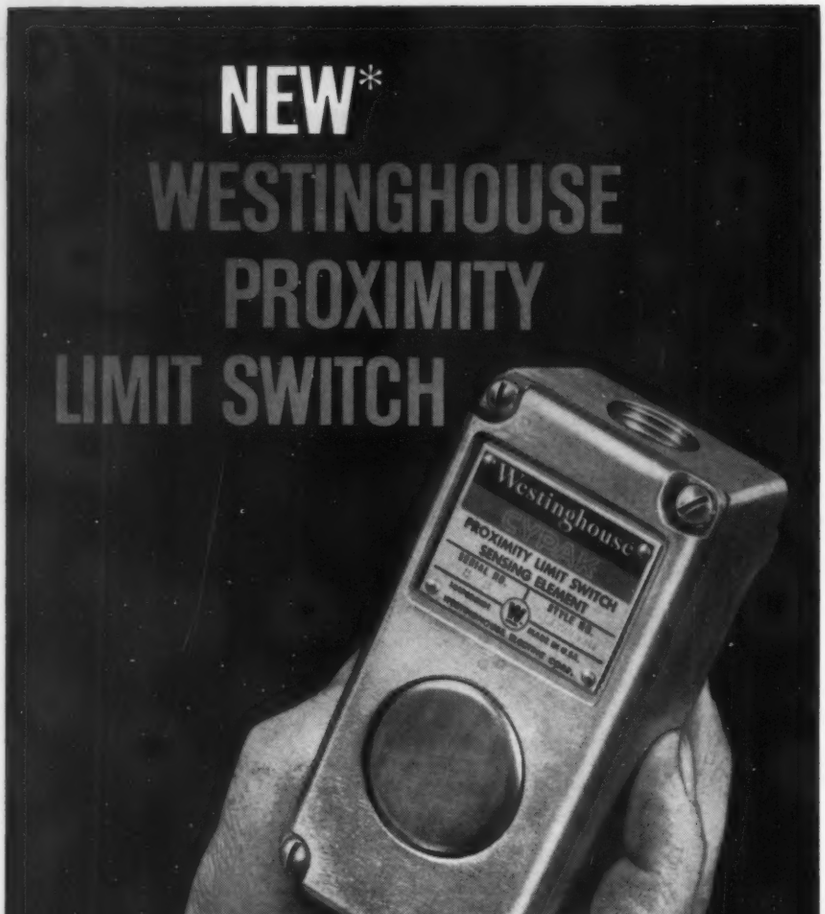
Union Switch & Signal, *Div. Westinghouse Air Brake, Pittsburgh 18, Pa.*

Vapor Heating Corp., *6420 W. Howard St., Chicago 31, Ill.*

Ward Leonard Electric Co., *115 MacQuesten Pkway, S., Mt. Vernon, N. Y.*
Warren Mfg. Co., Inc., The, *Littleton, Mass.*
Weston Instruments, *614 Frelinghuysen Ave., Newark 12, N.J.*
Worner Electronics Devices, *Rankin, Ill.*

ADVERTISERS' INDEX

Inquiry Number	ADVERTISERS	Page Number
	A	
34	Ace Plastic Co. *Richard-Lewis Advertising*	37
45	Allied Control Co., Inc. *Michel Cather, Inc.*	52
31	American Sealants Co. *Graceman Advertising, Inc.*	29
16	Amperite Co. *H. J. Gold Co.*	12
2	Applied Science Corp. of Princeton *Paul M. Healy Adv. Agency*	2
37	Associated Spring Corp. *The Davis Press, Inc.*	41
21	Automatic Electric Co. *Kudner Agency, Inc.*	17
	B	
12	Barden Corp., The *Gaynor & Ducas, Inc.*	7
9	Biddle, James G., Co. *The Roland G. E. Ullman Org., Inc.*	5
27	Bird, R. H. & Co. *Tippett & Co.*	22
8	Bodine Electric Co. *The Fensholt Adv. Agency*	5
58	Boehme, H. O., Inc. *Battista Advertising*	71
15	Bristol Co., The *James Thomas Chirurg Co.*	10
	C	
46	Consolidated Electrodynamics Corp. *Hixson & Jorgensen, Inc.*	53
49	Consolidated Electrodynamics Corp. *Hixson & Jorgensen, Inc.*	56
	D	
18	Dynamic Gear Co., Inc. *McClellan Advertising, Inc.*	15
	E	
29	Ebert Electronics *The Leonard Rattner Co.*	25
26	Edison, T. A., Ind. (Instrument Div.) *Gaynor & Ducas, Inc.*	20
13	Electro-Mec Laboratory, Inc. *Henry E. Salloch, Advertising*	8
47	Electronic Assembly Co., Inc.	54
	Electronic Assembly Co., Inc.	61
48	Elgin National Watch (Advance Relay Co.) *Balsam Advertising, Inc.*	55
22, 23, 24, 25	Engelhard Industries, Inc. *Stuart Sande, Advertising*	18, 19
	G	
52	General Electric (Defense Systems) *Deutsch & Shea, Inc.*	58
35	General Electric (LMED) *Deutsch & Shea, Inc.*	38
14	Grant Pulley & Hardware Corp. *Bernard Cooper, Advertising*	9
10	Graphic Systems *Diener & Dorskind, Inc.*	6
7	Guardian Electric Mfg. Co. *Kennedy & Co.*	3
	H	
53	Haydon (Div. of General Time) *Hugh H. Graham & Associates*	67
30	Haydon, A. W., Co. *Cory Snow, Inc.*	25
54	Heinze Electric Co. *Walter B. Snow & Staff, Inc.*	72
59	Hoffman Electronics Corp. *Sander Rodkin Advertising Agency*	Cover 3
	Hughes Aircraft Co. *Foote, Cone & Belding*	11
36	Hunter Spring Co. *Richardson, Thomas & Bushman, Inc.*	39
	I	
51	Instron Engineering Corp. *Larcom Randall Advertising, Inc.*	57
50	Instrument Development Labs, Inc. *Richard Thorndike Agency*	57
42	Iron Fireman Manufacturing Co. *Joseph R. Gerber Co.*	49
	K	
41	Kearfott Co., Inc. *Gaynor & Ducas, Inc.*	44
	L	
	Litton Industries (Electronic Equipments Div.) *Calkins & Holden, Inc.*	13
	M	
11	Mosinee Paper Mills Co. *The Buchen Co.*	6
	N	
3	NJE Corp. *Keyes, Martin & Co.*	24
6	National Co., Inc. *Burton Browne, Advertising*	60
	P	
60	Parker Seal Co. *Lester Voorhees Co.*	Cover 4
1	Potter & Brumfield, Inc. *Fletcher D. Richards, Inc.*	Cover 2
20	Power Sources, Inc. *Kenneth A. Young Assoc., Inc.*	16
44	Price Electric Corp. *H. W. Buddemeier Co., Inc.*	51
	S	
55	Servo Systems Co., The *Morcay Advertising Agency*	68
19	Sierra Engineering Co. *Guerin, Johnstone, Jeffries, Inc.*	15
28	Sigma Instruments, Inc. *Culver Advertising, Inc.*	23
17	Southwest Products Co. *O. K. Fagan Adv. Agency*	14
56	Southwest Products Co. *O. K. Fagan Adv. Agency*	68
32	Split Ballbearing (Div. MPB, Inc.) *Watson-Manning, Advertising*	34
5	Strong Electric Corp., The *Wendt Advertising Agency*	32
39	Sturtevant, P. A., Co. *Ross Llewellyn, Inc.*	43
4	Syntronic Instruments, Inc. *Burton Browne, Advertising*	31
	U	
38	United Electric Controls Co *S. Gunnar Myrbeck & Co., Inc.*	42
40	Universal Relay Corp. *Chelsea Advertising, Inc.*	43
	V	
33	Valcor Engineering Corp. *Keyes, Martin & Co.*	35
	W	
43	Westinghouse Electric Corp. *Fuller & Smith & Ross, Inc.*	50
57	Westinghouse Electric Corp. *Fuller & Smith & Ross, Inc.*	70



...WON'T WEAR OUT... NEVER NEEDS REPLACEMENT

No tubes . . . no moving parts to weaken and fail from wear . . . not affected by dust, dirt, oil mist or iron filings . . . will even operate under water . . . sensing heads available for distances of ½ inch and 2 inches . . . also for explosion-proof applications . . . corrosion and vibration resistant . . . won't spark, pit or wear, because there are no contacts.

Sure, they cost a little more initially. But we haven't seen the application yet where the new Westinghouse proximity limit switch can't pay for itself time and again through eliminated replacements and machine down time.

GET ALL THE FACTS about new Westinghouse proximity limit switches . . . see how and where they can benefit you. Write to Westinghouse Electric Corporation, Director Systems Department, 356 Collins Avenue, Pittsburgh 6, Pennsylvania. J-01011

YOU CAN BE SURE...IF IT'S Westinghouse

WATCH "WESTINGHOUSE LUCILLE BALL-DESI ARNAZ SHOWS" CBS TV MONDAYS

CIRCLE 57 ON INQUIRY CARD

PRODUCT INDEX TO ADVERTISING

Product	Page Number
Bearings, Ball, Precision	34
Bearings, Ball, Prec. Miniature	7
Bearings, Ball, Self-Aligning	14
Bearings, Jewel	22
Business Opportunities	61
Chains & Sprockets, Miniature	15
Connectors, Electrical	53
Controls, Oscillator	5
Controls, Remote, Push-Pull	68
Controls, Temperature	42
Controls, Temperature	50
Converters, Analog-Digital	57
Converters, Analog-Digital	44
Digitalizer, Shaft Angle	8
Dispenser, Spring	41
Employment Opportunities	58
Employment Opportunities	38
Employment Opportunities	11
Employment Opportunities	57
Employment Opportunities	13
Encoder, Digital, Shaft Position	2
Gears, Differential	15
Gears, Precision	71
Instruments, Data Processing	56
Inverters, Transistorized	16
Knobs, Control	60
Lamps, Carbon Arc Printing	32
Metals, Temp. & Voltage Control	18
Motor-Generator, Servo	68
Motors	5
Motors, Universal	72
Paper, Dielectric	6
Parts, Fabricated Plastic	37
Plating, Silver Liquid	19
Pots, Sine-Cosine	68
Power Supplies	54
Power Supplies	24
Quartz, Fused, High Purity	18
Regulators, Ballast	12
Relays	52
Relays	23
Relays	43
Relays, Delay	12
Relays, General Purpose	3
Relays, General Purpose	51
Relays, MH	Cover 2
Relays, Mercury Plunger	25
Relays, Miniature	55
Relays, Sensitive	20
Relays, Sensitive, Micro-Min.	49
Relays, Transistorized Time-Delay	25
Sealants, Liquid	29
Seals, WR Wave-Guide	Cover 4
Silicon Solar Cells	Cover 3
Slides, Vibration Control	9
Springs, Constant-Force	39
Switch, Miniature Pressure	10
Switches, Proximity Limit	70
Switches, Stepping	17
Timing Devices	67
Valves, Solenoid, Nylon-Body	35
Visual Control	6
Wire, Ductile & Non-Ductile	19
Wrenches, Torque	43
Yokes, Deflection	31

For Your 3-Ring Binder

NEW DATA SHEETS

For your free copy of the data sheets listed on this page, circle the appropriate number of the item on the Inquiry Card.

Cooling Packages

Cooling packages, designed for use in electronics systems requiring air-liquid coolant mediums, are particularly adaptable to systems utilizing liquid-cooled power tubes in both airborne and ground installations. The design stresses compactness, minimum weight and durability. Pesco Products Div., Borg-Warner Corp., Bedford, Ohio. Circle 177.

Electrical Switching Problem Solver

A new series of electrical programmers offer versatility in solving complex electrical switching problems. Among the many industrial and commercial applications for these programmers are vending machines, appliances, automation controls, industrial programming, and others where pre-determined electrical switching must be accomplished reliably, repeatedly and economically. Designed for volume production, these compact programmers can be readily adapted to a wide variety of special requirements, making them particularly useful for applications where low-cost and versatility are of primary concern. Bulletin AWH RC-202 contains illustrations, dimensional drawings and full specifications. The A. W. Haydon Co., Waterbury, Conn. Circle 221.

Explosion-Proof Switches

2-page data sheet describes the new series of rain-tight explosion-proof switches designed for use on fuel or chemical handling devices, missile launching equipment and other hazardous outdoor installations; photographs, dimension drawings, characteristics, mounting information, list prices and quantity discounts. Micro Switch, Div. of Minneapolis-Honeywell Reg. Co., Freeport, Ill. Circle 195.

Load Isolator Magnets

New catalog describes the basic sizes and shapes of "C" type Alnico V magnets available from stock for microwave load isolators. The Indiana Steel Products Co., Valparaiso, Indiana. Circle 173.

General Purpose Relays

Detailed dimensional drawings, available contact arrangements, current and coil operating data, operating speeds, terminals, weights, enclosures, terminal headers and mounting information for small multi-contact midgets to sensitive heavy duty, medium power and power types. Guardian Electric Mfg. Co., Chicago, Illinois. Circle 208.

Plug Valve

A 3000 psi Flo-Ball plug valve with zero leakage and one quarter turn positive opening and shut-off replaces the conventional needle valve. In non-throttling applications, the flo-ball valve completes the positive open and shut-off cycle in a 90 degree arc of travel, rather than the four to six turns required by a needle valve. Resembling an electrical panel switch, the valve handle responds to finger tip pressure and clicks into place at both ends of the quarter turn. The position of the handle indicates at a glance whether the valve is open or closed. The manufacturer reports that the valve can be used for gauge shut-off and with corrosive or other hard-to-handle fluids. Hydromatics, Inc., Livingston, New Jersey. Circle 175.

Vitreous Enamel Resistors

New fixed wire wound vitreous enameled resistors, now available in 3 watt, 5 watt, 10 watt and 20 watt types, have steatite type cores, continuous operating temperature of 134 degrees maximum at 40 degrees C. ambient. They are resistant to humidity, are furnished in 5% and 10% tolerances and have axial leads which make them simple to mount. Tru-Ohm Products, Div. of Model Engineering, Chicago, Ill. Circle 212.

Relay Catalog

39 pages of data on AC and DC general purpose units, plug-in, printed circuit, and telephone types. Also data on coils, solenoids and switch assemblies. Comar Electric Co., Chicago, Illinois. Circle 168. *Continued on page 72*

at your wits end...

Looking for custom-made fine pitch precision gears???

The production of custom-made, fine pitch precision gears is part of the daily routine at Boehme. Whatever your precision gear needs—up to A.G.M.A. precision #3, ⅛" to 5" O.D., 180 to 16 D.P.—our specialized engineering skills and excellence of craftsmanship produce the precision gears or gear trains that meet your specific problem.

We have been in the business of design and manufacture of precision equipment, since 1917. Boehme electrical, electro-mechanical and electronic products are setting precision standards for the rapidly progressing fields of automation and instrumentation. Our specialty is meeting your precision manufacturing requirements.

Let us submit estimates of your needs based on your sketches or blueprints, at no cost or obligation to you. Write now, for more information.

H. O. Boehme, Inc.

Contractors, Designers, Manufacturers of Precision Electrical, Electro-Mechanical and Electronic Equipment since 1917

915 Broadway
New York 10, N. Y.

CIRCLE 58 ON INQUIRY CARD

put HEINZE in your designs

POWER

in compact size...

HEINZE UNIVERSAL MOTORS

When you want power in compact series motors, Heinze Universal Motors provide high starting torque, variable speed, reversibility and high output. Originally developed for sewing machines and office machines, they are extremely flexible in design for a variety of uses not requiring constant speed. Flat sided models are especially adaptable for limited space.

Horsepower ratings are from 1/10 to 1/30. Load speed is 7,500 rpm. Standard voltage rating is 115V, AC/DC but motors are supplied for other voltages in AC or DC. Rotation is CW, CCW, or reversing. Optional mounting arrangements include tapped holes on flat side.

Send coupon for new catalog on Heinze Universal Motors — plus the complete line of Heinze sub-fractional horsepower motors and blowers.

HEINZE ELECTRIC COMPANY
685 Lawrence St.
Lowell, Massachusetts

Heinze Electric Company
Dep't ED 685 Lawrence Street
Lowell, Massachusetts

Please send new catalog on Heinze sub-fractional motors and blowers.

Name & Title.....

Company.....

Street & No.....

City & State.....

CIRCLE 54 ON INQUIRY CARD

Microwave Components

Comprehensive data sheets on parabolic antennas and accessories, passive reflectors, commercial communication antennas, and waveguide and transmission lines; also data on communication antennas. Gabriel Electronics Div. of Gabriel Co., Needham Hgts., Mass. Circle 188.

Elapsed Time Indicator

Utilizing jewel bearings and a precision gear train, with a ratio of 1.8 billion to 1, it weighs only 3 ounces. Measuring 1 1/16 OD x 1 15/16 it has a 10,000 hour total readout. 2-hour scale divisions permit readings to the closest hour. Data sheet gives outline dimensions and operational data. Waltham Precision Instrument Co., Waltham, Mass. Circle 191.

Fact File on Mercury Plunger Relays

Load ratings, contact data, coil characteristics, mounting dimensions, diagrams, illustrations and technical articles on application engineering. Ebert Electronics Corp., Queens Village, N.Y. Circle 207.

Direct Lift Solenoid Valve

New 2 way direct lift solenoid valve handles steam, air, gas, light oil, water and other non-corrosive liquids and gases. Data sheet contains complete description and application details. Automatic Switch Co., Florham Park, New Jersey. Circle 186.

High Temperature Synchros

New series of Size 8 and Size 11 synchros are designed to operate effectively over a temperature range of −54C to 200C. Size 11 components are high performance synchros incorporating the most advanced temperature resistant parts and impregnating materials. Size 8 units, suited to missile applications where space and weight considerations are critical. Both types are 400 cycle synchros, and have a maximum error from electrical zero to 10 min. Detailed performance characteristics available. Kearfott Co., Inc., Clifton, New Jersey. Circle 227.

Wave Guide Seals

A complete line of seals for WR-series and X-brand wave guides provide no-leakage fluid sealing, prevent R/F leakage and eliminate burning and/or arcing. Called Electr-O-Seals, the new seals are made to fit EIA (RETMA) standard guides and, in addition to positive sealing, provide savings by making special machining of flanges unnecessary. The inside metal mating edges of the seal are knurled to assure positive electrical contact. They are also reusable. Parker Seal Co., Culver City, Calif. Circle 187.

Standard Inductors

A new, standard line of metallized glass inductors designed for tuned circuit applications at frequencies above 30.0 megacycles become available in April on an off-the-shelf basis. Corning Glass Works, Electronic Components Dept., Bradford, Pa. Circle 206.

Power Supplies

Transistorized, short circuit proof power supplies cover a complete range starting at zero. They can be used from a fraction of one volt to any voltage up to 60 without loss of regulation or stability. Available with maximum current ratings of 2.5A, 5A, and 7.5A. Electronic Measurements Co. of Red Bank, Eatontown, N. J. Circle 200.

New Servo Motor

A new 2-phase instrument servo motor is available as a basic servo unit; bulletin shows how four different gear types meet various application requirements. Holtzer-Cabot Motor Div. of National Pneumatic Co., Inc., Boston, Mass. Circle 209.

DC-DC Static Converter

DC-DC Static Converter for computer, portable test equipment and airborne equipment applications; unit is hermetically sealed and has been designed so that it is insensitive to physical orientation. Magnetic Research Corp., Hawthorne, Calif. Circle 179.

"Valve Finder" Catalogs

The Hannifin "Valve Finder" contains an informative discussion of air valves and their selection together with condensed catalog listings. The first section provides an explanation of valve terms and principles used in the air control valve industry. Included is a 3-step outline covering valve types, means of actuation and operating principles to simplify choosing the exact air control valve best suited for any application. Hannifin Co., Dept. 264, Des Plaines, Ill. Circle 184.

High Temperature Synchros

High temperatures synchro, size 11, is capable of withstanding a 450F ambient temperature and of meeting the normal MIL-S-2335 specification requirements as to accuracy, etc. Models are being manufactured in the 115-volt torque transmitter and control transformer types, with other types becoming available shortly. Size 23 synchro can withstand an ambient temperature of 350F and also meets the requirements of MIL-S-2335 in all of the respects. Montrose Div. of Bendix Aviation, So. Montrose, Pa. Circle 223.

CHANGE OF ADDRESS

PRESENT CO. ADDRESS

PRESENT CO.

CITY

ZONE

STATE

Circle the code number for more information on editorial or advertised items. Code numbers for advertisements are listed in Advertiser's Index and when possible are set in the ad.

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81	82	83	84
85	86	87	88	89	90	91	92	93	94	95	96
97	98	99	100	101	102	103	104	105	106	107	108
109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132
133	134	135	136	137	138	139	140	141	142	143	144
145	146	147	148	149	150	151	152	153	154	155	156
157	158	159	160	161	162	163	164	165	166	167	168
169	170	171	172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189	190	191	192
193	194	195	196	197	198	199	200	201	202	203	204
205	206	207	208	209	210	211	212	213	214	215	216
217	218	219	220	221	222	223	224	225	226	227	228
229	230	231	232	233	234	235	236	237	238	239	240
241	242	243	244	245	246	247	248	249	250		

To facilitate processing your inquiries please check the appropriate box below.

☐ I am now ON your circulation list

☐ I am NOT on your circulation list

ELECTROMECHANICAL
components & systems | **DESIGN**

Please use this card before June 15

IF YOU ARE NOT ON OUR CIRCULATION LIST, YOU CAN QUALIFY FOR A YEAR'S FREE SUBSCRIPTION BY ANSWERING THE FOUR QUESTIONS BELOW

1. My major engineering function in research, development or design is: (check one only) ☐ *Electronic* ☐ *Electromechanical* ☐ *Mechanical*

2. My major non-engineering function in research, development or design is: (check all that apply) ☐ *Management* ☐ *Purchasing* ☐ *Production* ☐ *Other* _____

3. Principal product(s) manufactured by my company at the address below:

_____

4. No. of engineers in my dep't. _____, in my company _____

PLEASE PRINT

NAME _____ TITLE _____

COMPANY _____

COMPANY ADDRESS (ST.) _____

CITY _____ ZONE _____ STATE _____

Signature _____

Postage
Will Be Paid
by
Addressee

No
Postage Stamp
Necessary
If Mailed in the
United States

BUSINESS REPLY CARD

First Class Permit No. 13772 • New York, N. Y.

ELECTROMECHANICAL DESIGN

1357 WASHINGTON STREET

WEST NEWTON 65, MASS.

A HOFFMAN SEMICONDUCTOR APPLICATION CASE HISTORY

THIS CONTROL PROBLEM HAD TO BE SOLVED

For new semiconductor application ideas, visit Booths 3242-3243 at the I.R.E. Show

FOR AUTOMATIC DOLLAR BILL CHANGERS

Hoffman Silicon Solar Cells were the solution

A.B.T.'s (division of Atwood Vacuum Machine Co., Rockford, Illinois) intricate control problem in their unique "bill changer" required Hoffman Silicon Solar Cells, of exacting quality, to automatically register the authenticity of a dollar bill, in this innovation in automatic vending.

You, too, may have a control problem requiring immediate and accurate registering—instantaneous response (20 microseconds)—long life (10,000 years*)—high light conversion efficiency (up to 10%)—wide spectral response range (4,000-11,500 angstroms)—extended operating temperature range (—65°C to +175°C).

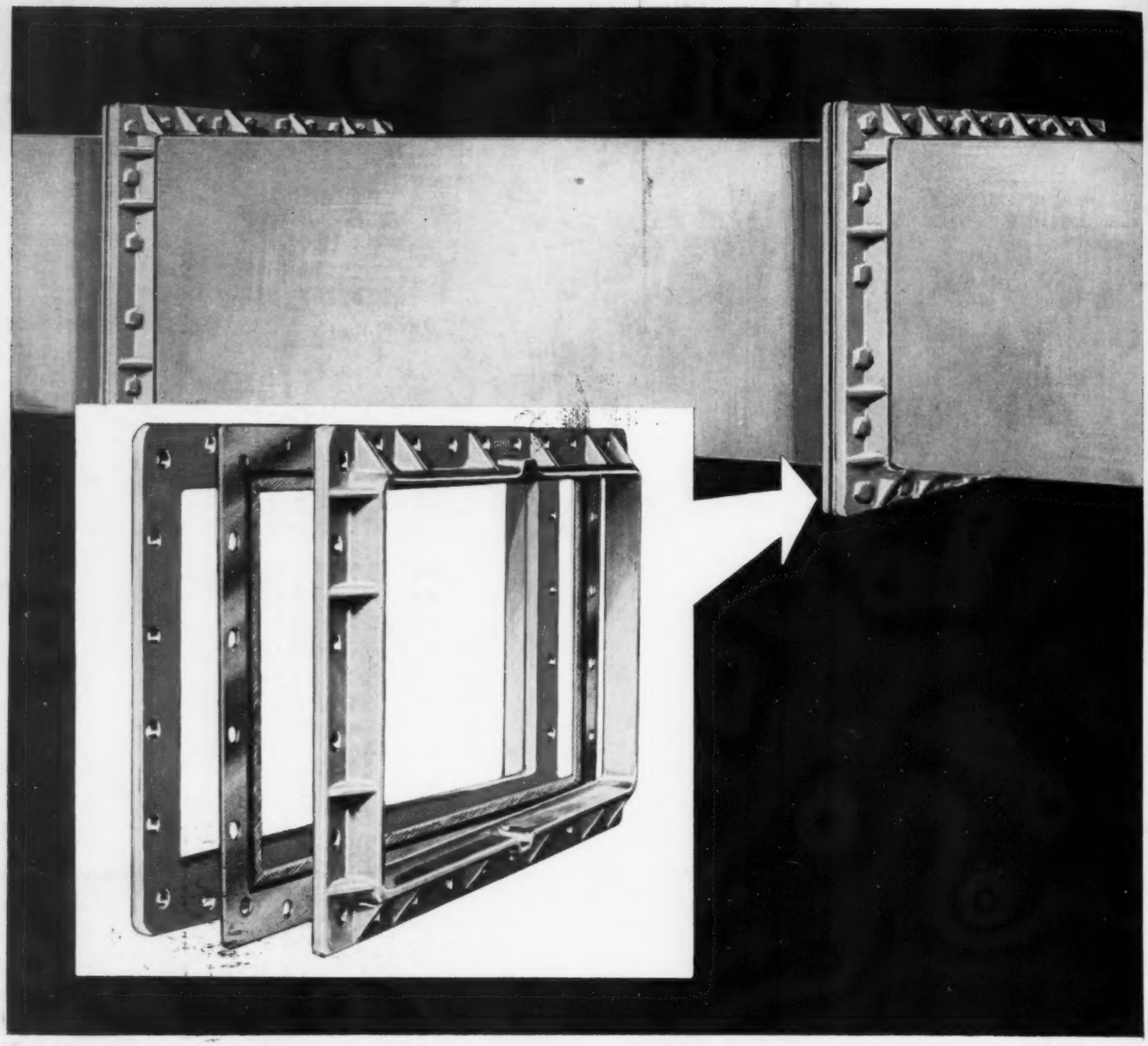
Hoffman Silicon Solar Cells, born from the same family as those which are still powering the U. S. Navy's Vanguard satellite's radio transmitter, can be the answer to your control problem. For details consult the Hoffman Solar Cell applications specialist in your area or write to Department SS.

If you need a job in electronics done quicker and better, contact

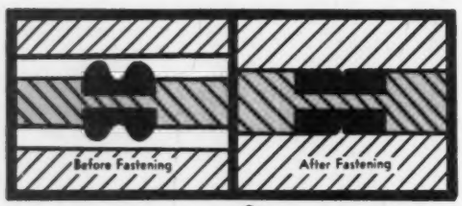
Hoffman Electronics CORPORATION
SEMICONDUCTOR DIVISION
930 PITNER AVENUE EVANSTON, ILLINOIS

*(Per R.C.A. Laboratories, Princeton, New Jersey, Report No. 212-PH-55-91 [1114], April 15, 1957)

CIRCLE 59 ON INQUIRY CARD



THESE WR WAVE GUIDE SEALS PROVIDE POSITIVE SEALING; PREVENT R/F LEAKAGE, ARCING & BURNING



Electr-O-Seals are now available to fit all EIA (RETMA) standard WR series wave guide flanges, WR90 thru WR2300 as well as specials.

These seals not only provide near perfect sealing and complete electrical continuity, but offer many economical advantages — made by the makers of Parker O-rings, Stat-O-Seal®, and Gask-O-Seal®.

Parker SEAL COMPANY

CULVER CITY, CALIFORNIA and CLEVELAND, OHIO

A DIVISION OF PARKER-HANNIFIN CORPORATION

CIRCLE 60 ON INQUIRY CARD

VE
NG
)
mical
NY
OHIO
TION

put HEINZE in your designs

POWER

in compact size...

HEINZE UNIVERSAL MOTORS

When you want power in compact series motors, Heinze Universal Motors provide high starting torque, variable speed, reversibility and high output. Originally developed for sewing machines and office machines, they are extremely flexible in design for a variety of uses not requiring constant speed. Flat sided models are especially adaptable for limited space.

Horsepower ratings are from 1/10 to 1/30. Load speed is 7,500 rpm. Standard voltage rating is 115V, AC/DC but motors are supplied for other voltages in AC or DC. Rotation is CW, CCW, or reversing. Optional mounting arrangements include tapped holes on flat side.

Send coupon for new catalog on Heinze Universal Motors — plus the complete line of Heinze sub-fractional horsepower motors and blowers.

HEINZE ELECTRIC COMPANY
685 Lawrence St.
Lowell, Massachusetts

Heinze Electric Company
Dep't ED 685 Lawrence Street
Lowell, Massachusetts

Please send new catalog on Heinze sub-fractional motors and blowers.

Name & Title.....
Company.....
Street & No.....
City & State.....

CIRCLE 54 ON INQUIRY CARD

Microwave Components

Comprehensive data sheets on parabolic antennas and accessories, passive reflectors, commercial communication antennas, and waveguide and transmission lines; also data on communication antennas. Gabriel Electronics Div. of Gabriel Co., Needham Hgts., Mass. Circle 188.

Elapsed Time Indicator

Utilizing jewel bearings and a precision gear train, with a ratio of 1.8 billion to 1, it weighs only 3 ounces. Measuring 1 1/16 OD x 1 15/16 it has a 10,000 hour total readout. 2-hour scale divisions permit readings to the closest hour. Data sheet gives outline dimensions and operational data. Waltham Precision Instrument Co., Waltham, Mass. Circle 191.

Fact File on Mercury Plunger Relays

Load ratings, contact data, coil characteristics, mounting dimensions, diagrams, illustrations and technical articles on application engineering. Ebert Electronics Corp., Queens Village, N.Y. Circle 207.

Direct Lift Solenoid Valve

New 2 way direct lift solenoid valve handles steam, air, gas, light oil, water and other non-corrosive liquids and gases. Data sheet contains complete description and application details. Automatic Switch Co., Florham Park, New Jersey. Circle 186.

High Temperature Synchros

New series of Size 8 and Size 11 synchros are designed to operate effectively over a temperature range of −54C to 200C. Size 11 components are high performance synchros incorporating the most advanced temperature resistant parts and impregnating materials. Size 8 units, suited to missile applications where space and weight considerations are critical. Both types are 400 cycle synchros, and have a maximum error from electrical zero to 10 min. Detailed performance characteristics available. Kearfott Co., Inc., Clifton, New Jersey. Circle 227.

Wave Guide Seals

A complete line of seals for WR-series and X-brand wave guides provide no-leakage fluid sealing, prevent R/F leakage and eliminate burning and/or arcing. Called Electr-O-Seals, the new seals are made to fit EIA (RETMA) standard guides and, in addition to positive sealing, provide savings by making special machining of flanges unnecessary. The inside metal mating edges of the seal are knurled to assure positive electrical contact. They are also reusable. Parker Seal Co., Culver City, Calif. Circle 187.

Standard Inductors

A new, standard line of metallized glass inductors designed for tuned circuit applications at frequencies above 30.0 megacycles become available in April on an off-the-shelf basis. Corning Glass Works, Electronic Components Dept., Bradford, Pa. Circle 206.

Power Supplies

Transistorized, short circuit proof power supplies cover a complete range starting at zero. They can be used from a fraction of one volt to any voltage up to 60 without loss of regulation or stability. Available with maximum current ratings of 2.5A, 5A, and 7.5A. Electronic Measurements Co. of Red Bank, Eatontown, N. J. Circle 200.

New Servo Motor

A new 2-phase instrument servo motor is available as a basic servo unit; bulletin shows how four different gear types meet various application requirements. Holtzer-Cabot Motor Div. of National Pneumatic Co., Inc., Boston, Mass. Circle 209.

DC-DC Static Converter

DC-DC Static Converter for computer, portable test equipment and airborne equipment applications; unit is hermetically sealed and has been designed so that it is insensitive to physical orientation. Magnetic Research Corp., Hawthorne, Calif. Circle 179.

"Valve Finder" Catalogs

The Hannifin "Valve Finder" contains an informative discussion of air valves and their selection together with condensed catalog listings. The first section provides an explanation of valve terms and principles used in the air control valve industry. Included is a 3-step outline covering valve types, means of actuation and operating principles to simplify choosing the exact air control valve best suited for any application. Hannifin Co., Dept. 264, Des Plaines, Ill. Circle 184.

High Temperature Synchros

High temperatures synchro, size 11, is capable of withstanding a 450F ambient temperature and of meeting the normal MIL-S-2335 specification requirements as to accuracy, etc. Models are being manufactured in the 115-volt torque transmitter and control transformer types, with other types becoming available shortly. Size 23 synchro can withstand an ambient temperature of 350F and also meets the requirements of MIL-S-2335 in all of the respects. Montrose Div. of Bendix Aviation, So. Montrose, Pa. Circle 22